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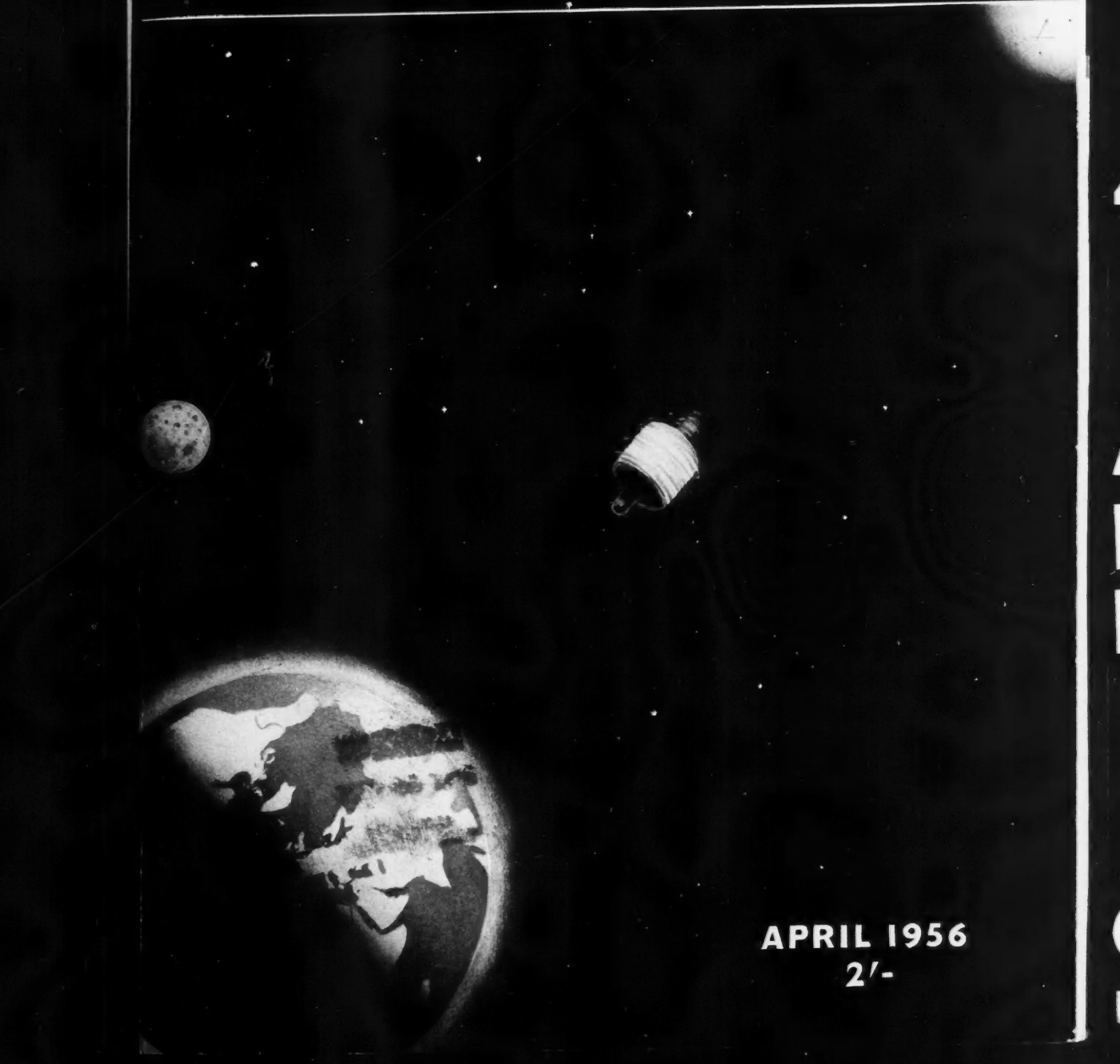

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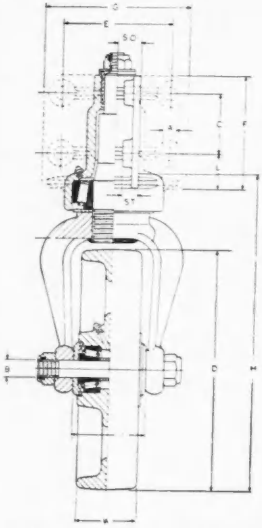

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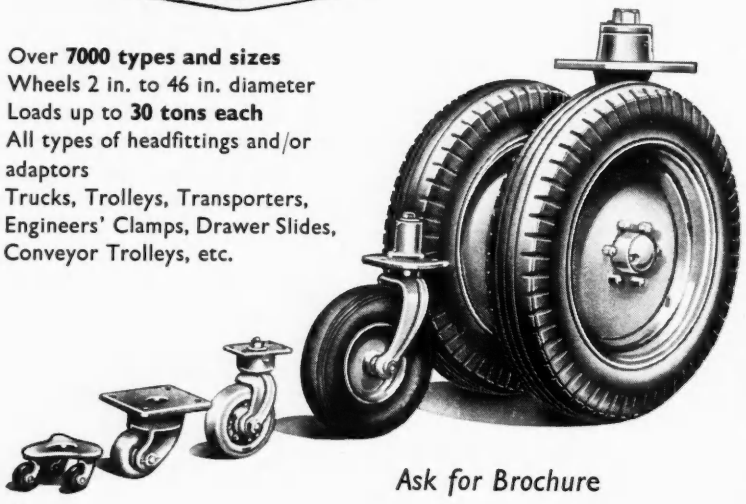

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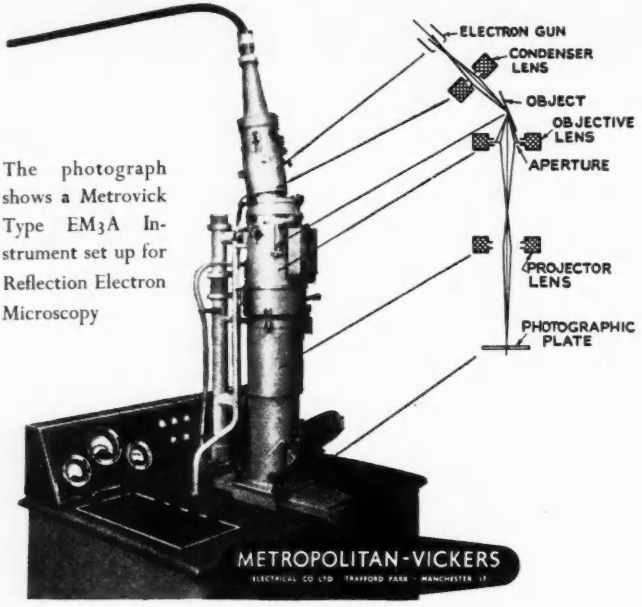

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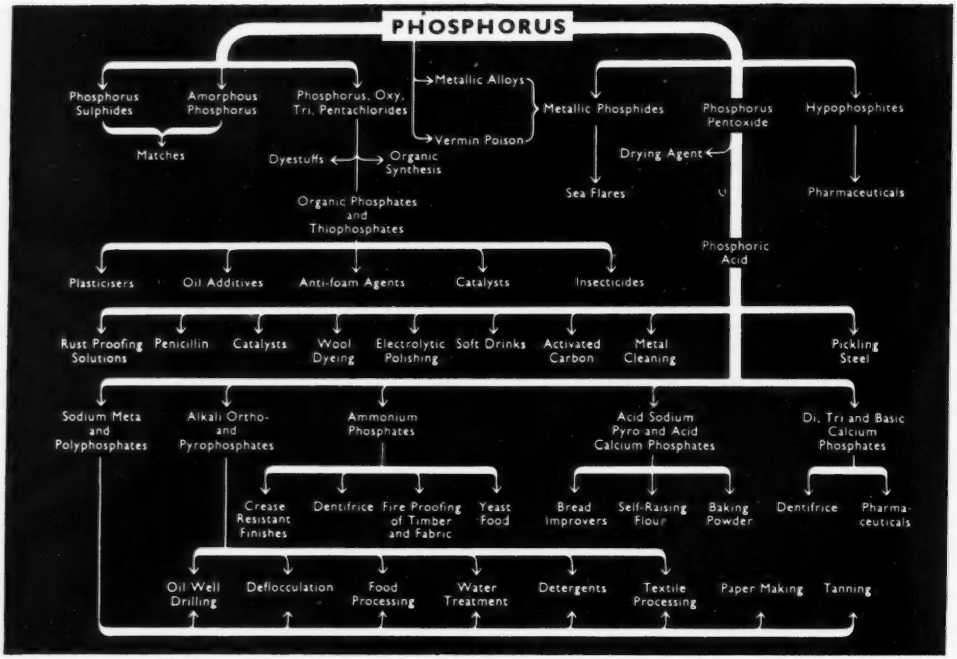

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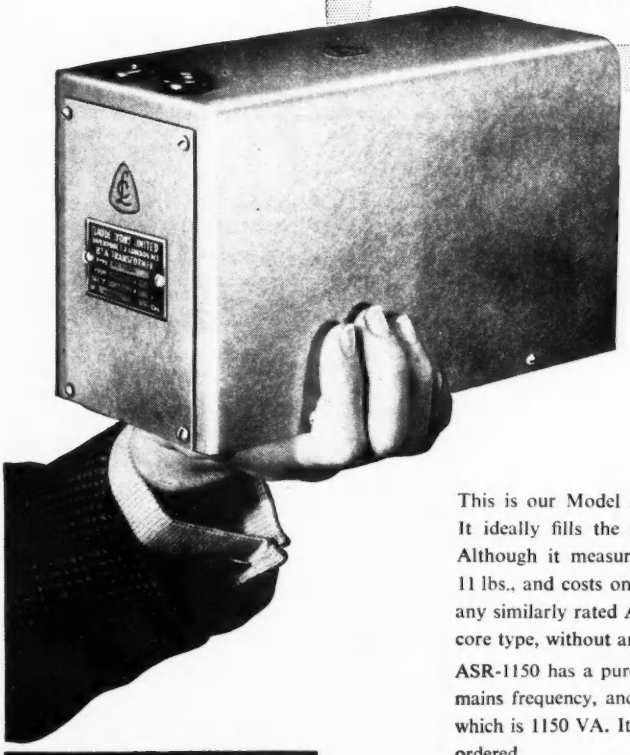

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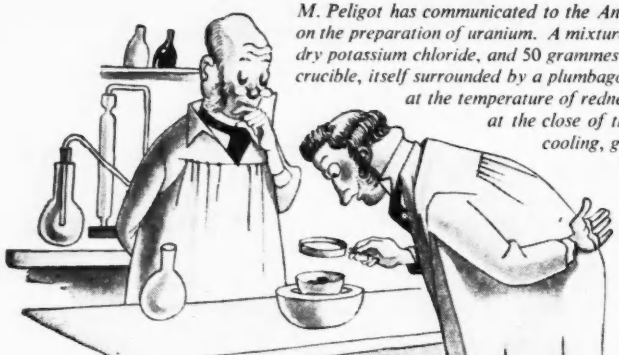
COVER PICTURE: An artist's impression of MOUSE, the Artificial Satellite in flight

CHANGE OF EDITORSHIP

Mr. William E. Dick, who for the last twelve years was Editor of *Discovery*, has now taken up the position of Editor of a new journal, *British Chemical Engineering*. His many years of devoted work have made *Discovery* the journal it is today. He is succeeded by Dr. Anthony R. Michaelis, who is well known to many of our readers for his work in the application of cinematography to all branches of science.

M. Peligot finds uranium



M. Peligot has communicated to the Annales de Chimie et Physique (xvii, 363) a short note on the preparation of uranium. A mixture of 75 grammes of uranous chloride, 150 grammes of dry potassium chloride, and 50 grammes of sodium in fragments is introduced into a porcelain crucible, itself surrounded by a plumbago crucible. The reaction is effected in a wind furnace at the temperature of redness; but the heat must be increased for a short time at the close of the operation. In the black slag may be found, after cooling, globules of fused uranium.

The new method of producing uranium was announced in the first issue of Nature in 1869. Monsieur Peligot, who twenty-eight years before had first isolated the metal, discovered by Klaproth in 1789, was opening the door a little more widely to the possibility of an Atomic Age a century later.

In recent years the priority attaching to the atomic energy programme has restricted their availability, but uranium compounds are now again available and figure among the several thousand fine chemicals of very high purity supplied by B.D.H. for science and industry.

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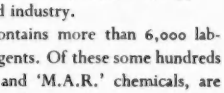

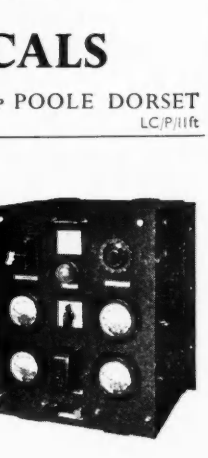

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THE PROGRESS OF SCIENCE

HAS THE PENNY REALLY DROPPED?

Sir David Eccles, Minister of Education, assured the technical press at a conference at his Ministry on February 29 that "the penny had dropped"; that the Government is fully aware of the urgent need to increase facilities for technological education in this country; that a sum of £97 million has been set aside for this purpose, and that no cuts, restrictions, delays and postponements of any kind would stand in the way of the fulfilment of his programme. He explained to the press conference, as he had done earlier to the House of Commons, that successful technological education was the *sine qua non* for the economic survival of this country. But has Sir David and his Ministry really tackled this problem in the right way?

A reading of the White Paper shows that the Government has certainly taken many important steps. Much more is to be spent on building. The number of students in science and technology, already doubled since 1938, is to be further increased, new awards are to be made, and "sandwich classes" are to be extended in industry. Sir David hopes that the whole "climate" of the country's attitude to science will change and become more favourable, so that more young boys and girls will enter the technological professions. But a great deal of public support is required for this from local authorities, from industry itself, from the heads of schools, and from parents. How are Sir David and his Ministry going to achieve this? The publishing of a White Paper is hardly enough to alter the fundamental attitude of people in this country towards science and technology.

Not so long ago this country was faced with a similar desperate situation during war-time. If then such figures as: U.S.A. 136, Soviet Union 280, France 70, Germany 86, Switzerland 82, and Great Britain only 57 had been published for the monthly production of fighter aircraft, the situation would have been more than desperate. These figures, published today for university graduates per million of population, are no less desperate. And yet the measures proposed by the Government are surely inadequate as a remedy. During the war it became evident that scientific advice could be used in all fields, and decisions at all levels of waging war consequently benefited from this novel attitude. The outstanding success of operational research techniques in determining the optimum size of convoys, in assessing bomber losses, in land fighting, mine-laying and so forth, are too well known to all scientists to need emphasising here. Has the Minister of Education considered the use of operational research methods to help him in his efforts to increase the number of technologists in this country An institute to carry out research is available in the National Foundation for Educational Research, set up to deal specifically with these problems. Are sufficient money and staff available for the Foundation to carry out its all-important task?

Many of the obstacles are well known. It is generally admitted that there are too few teachers of science in schools. A cautionary tale was told by Price (1956).

> "He [the chemistry master] expected us to work out little sums about hydrogen instead of simply lighting it. However, he was not a very firm young man and we soon slid into the lazy habit of mixing a pinch of every chemical in sight and then, for old times' sake, boiling it. Soon we were too near to School Certificate to permit periods being diverted from the Classics and I never had a science lesson again. I left school thinking science was a slightly contemptible method of giving us the kind of therapeutic time-wasting that heavy mental effort needed. In a girls' school, I felt, it might take the form of raffia work."

Non-scientists are hardly receiving any scientific training, and the time available for teaching science to scientists themselves is often thought to be inadequate. Would it be impossible to find an answer to these problems if operational research techniques were brought to bear? Surely it would be an advantage in tackling this vast and complex human problem to begin at the basic problems and to inaugurate some research into its solution. Is there not an urgent need for the Ministry to think about fundamental education research and to allocate funds for this specific purpose? Surely if £97 million are to be spent, at least 5 or 10% of that sum might be devoted to research on the fundamental questions: How can science and technology best be taught and how can the maximum number of young people be persuaded to take up these subjects for their vocation? Is the present structure of education in this country capable of dealing with the whole question of technological education?

There are many unsolved questions in education, and new techniques and methods have been developed in recent years. For example, a technique for increasing the speed of reading has been studied by Imperial Chemical Industries, and it has been suggested that such a technique could help executives who devote much of their time to this form of work. Could students benefit by its application, or is the retention of material read at great speeds insufficient for learning? Nor is this country sufficiently up to date in its use of visual aids. When General Keitel, the German Chief of Staff, was interviewed at the end of the war and asked to state his reasons for Germany's defeat, he mentioned that one of the causes was that his own country had overestimated the time required to train British and American soldiers in the handling of the complex weapons of modern war. By an efficient and thorough use of all visual aids, films, film-strips, wall charts, and models, the British and American armed forces were able to reduce the training

Price, R. G. G., "Non-Scientist", *Punch*, 1956, vol. 230, p. 276.

time far below that required by the equivalent German services.

These lessons, so dearly learned in war, could surely be applied with equal success in peace-time when the situation is no less urgent. Are the Minister of Education and his staff convinced that there are no lessons to be learned from teaching institutes abroad? Are we using the most up-to-date equipment in our schools and in our technological colleges? Is the available money spent in the most efficient way? Is it not essential for fundamental research to be undertaken on educational techniques and their applications at all levels from school to university, before we can solve the situation that confronts this country at the present time?

ROYAL SOCIETY ANTARCTIC EXPEDITION

The first direct news and photographs of the Royal Society Antarctic Expedition's Base in Coats Land reached London at the end of February. On February 26, Mr. George Hemmen, expedition stores officer, arrived by air from Montevideo, having left Coats Land with the *Tottan*, the 540-ton sealer which conveyed the expedition members and stores to Antarctica. After taking part in the first three weeks' work of unloading stores and building, Mr. Hemmen is back in this country to order equipment and supplies in the light of his experience of the base site. He will return to Coats Land with the expedition's main party in November.

Mr. Hemmen's account of the expedition advance party's voyage south and search for a suitable base, supplements the official announcement. The *Tottan* left South Georgia on Boxing Day and the base was established on January 6. Mr. Hemmen described the probe southward and frequent trial landings that filled the period between these two dates.

Two days after leaving South Georgia, the party saw the first ice. This was the start of the heavy pack-ice across the mouth of the Weddell Sea. It took three days to pass through this to the clear water beyond; their way taking them zig-zag in a general south-easterly direction. "Every time we saw ice westerly we turned away a little east." By the time the *Tottan* was through this heavy pack she was well over to the eastern side of the Weddell Sea close to Coats Land. The captain now took a course south for Vahsel Bay, to which it was hoped the ship might be able to penetrate. Three days' steaming through clear water (December 31 to January 3) brought them into more heavy pack-ice screening the approach to Vahsel Bay.

Three times the ship became stuck but an explosive charge was only once needed to get her clear. During this stage of the trip Surgeon Lieutenant-Commander Dalgleish, the expedition leader, investigated several possible landing-places on the ice-sheathed shore of Coats Land. Three skiers were put ashore on the flat shelf of sea-ice projecting some distance beyond the 100-foot ice-cliffs which mark the beginning of the land itself in this region. They skied to the top of the cliffs which effectively screened the nature of the surface beyond. On each of these occasions the landing party had the same experience: "access was excellent, but, inland, it was terrible". During one of these investigations inland, Commander Dalgleish had all the stores out on the ice for sorting and for practice unloading.

On January 5 the *Tottan* made south again. "This time we got a little farther. There was a narrow 'lead' through but it was not wide enough for the ship. To go on would have been asking for trouble—more than asking for trouble, in fact." The situation was very tantalising, however, "for we knew that in the pocket of Vahsel Bay there would have been clear water. We could see the dark reflection of water beyond on the low cloud." (A "water-sky" of this sort when there is cloud can give an excellent indication of conditions ahead and is a substantial aid in navigation.) In the

THE ROYAL SOCIETY'S INTERNATIONAL GEOPHYSICAL YEAR EXPEDITION ADVANCE PARTY. FIG. 1 (*left*) shows members of the party at work on the foundation of the 130-foot hut which will be their home. All around are stores and material landed on the shore from the *Tottan*. FIG. 2 (*right*) shows members of the advance party at Coats Land. From left: J. E. Raymond (chief carpenter), D. S. W. Limbert (meteorologist), K. E. C. Powell (diesel engineer), Major G. E. Watson, R.E.M.E. (chief electronics engineer), C. P. Le Feuvre (wireless operator), R. Dalgleish (tractor driver), G. Lush (tractor driver), Surgeon Lt.-Cmdr. D. Dalgleish, R.N. (leader of the advance party), Dr. S. Evans (scientific officer), D. Prior (carpenter).

circumstances the expedition leader agreed not to attempt further progress south, and after waiting for some hours in case the wind might free the pack, the *Tottan* struck east. On this day, January 5, the party reached their farthest point south, 76° 36′ S., 28° 40′ W.

Next morning, January 6, a landing was made on the sea-ice shelf of Coats Land at 75° 36′ S., 26° 45′ W. A site slightly inland from this spot proved entirely suitable for the base. In contrast to the places previously investigated, a smooth flat plateau of ice extended back beyond the low ice-cliffs. "It was dead flat, no rock, no hills, no cracks—in fact nothing to see at all" in Mr. Hemmen's account.

The Base was established 2¼ miles straight inland from the *Tottan's* mooring and 1½ miles from the low cliffs that marked the beginning of land. (The shelf of sea-ice extended initially about three-quarters of a mile. During the course of the three-weeks' unloading operations however, portions of the outer edge broke off, gradually reducing the ice-shelf by about half its original width. This made the hauling of stores shorter, but more hazardous.

The site fulfilled Dalgleish's instructions to establish the base "South of 75°". Radio communications are likely to be better here than near Vahsel Bay.

Wind is an important factor when planning to spend the winter season in the Antarctic, especially where it is perfectly flat. The ice surface was studied, before siting the large base hut, for indications of the prevailing wind's direction and force. There was no evidence of any kind. This suggested that either there was no wind —or, that the wind's force was of such violence that it wiped the ice clear!

Mr. Hemmen pointed out that establishing the base proved "a lot less difficult than expected". The party had been prepared to take the stores five to six miles inland. They only had to be moved 2¼ miles. The landing-place, near a bay converging to a point between two ice-headlands, gave access to the interior plateau via a gentle slope. And by working at night when the temperature dropped a little below freezing, it was possible to use the tractors. They sank into the slushy snow-surface by day. The weather was fine throughout the first week of landing.

The main wireless transmitter came into operation on February 18. Before the *Tottan* sailed on January 22 the "raft" of timber on which the hut is built was complete: some members of the expedition moved into the hut's living-quarters during the last days of February.

The advance party has with them two unusual scientific instruments: a Dobson spectrophotometer for measuring ozone in the atmosphere, and the all-sky camera. This will be the highest latitude that the spectrophotometer has been used. The camera is of American design but the advance party will be the first users in Antarctica.

Last news of the Soviet Antarctic Expedition before going to press was that their ships, *Ob* and *Lena*, had stuck in the ice some distance from Mirny Base and personnel had been evacuated to Mirny by helicopter. At Mirny eighteen Arctic-type houses are up and central heating had been turned on in four of them.

HAFNIUM METAL TECHNIQUES

Hafnium metal, important in the atomic energy field, can be produced in the same equipment used for its sister substance, malleable zirconium, the metal which has proved so valuable in constructing nuclear reactors.

Reporting this recently, the U.S. Bureau of Mines said that techniques for producing hafnium had been developed at its North-west Electro-development Laboratory at Albany, Oregon, as part of a programme to recover rare metals from domestic and foreign ores. Details of the hafnium production process are described in a technical report released last December.

Hafnium and zirconium have widely different characteristics in the field of atomic energy. Zirconium does not absorb neutrons and thus is used as a structural and cladding unit in nuclear power units.

Hafnium, on the other hand, absorbs neutrons so effectively that it can be used as a radiation shield.

To meet the requirements of the Atomic Energy Commission, the Bureau of Mines created a process for making hafnium-free zirconium. The high-grade hafnium product of the process is treated to yield pure hafnium, which is now produced in sufficient quantities for testing its usefulness on a large scale.

Hafnium and zirconium are so closely related that the identity of hafnium remained undetected until 1923, when the element was discovered by Danish researchers.

The U.S. Bureau of Mines also reported that the oxide and carbide of hafnium have extremely high melting points and thus might have some future role in jet engines.

ATOMIC POWER FOR AIRCRAFT

Rolls-Royce has recently announced that it is working on the development of atomic power units for aircraft. Research work on light-weight reactors has, in fact, been going on for the past eighteen months.

The successful evolution of a practical atomic engine for aircraft depends on the solution of problems requiring unusual and frequently novel research equipment which has to be specially designed and constructed to high standards of accuracy and safety. A hint as to the nature of one of the most complex of these problems is contained in an announcement which states that the research team has been supplemented with specialists from outside, one of whom is Dr. S. G. Bauer from Harwell, an authority on high-temperature liquid metals.

It is probable that atom-powered aircraft will employ the jet propulsion system in one form or another. But whereas the efflux temperature of a conventional turbojet may reach 1300–1500°F, it may reach as much as 4000°F in an atomic engine. Consequently, the development of metals which boil only at very high temperatures is of prime importance.

In one version of an atomic engine the cycle of operation would be similar to that of a turbojet—air being drawn in through the intake, compressed, mixed

with fuel and detonated in the combustion chambers, and released, thus propelling the aircraft and, at the same time, revolving the turbine which turns the compressor. The combustion chambers would be replaced in an atomic engine by a reactor, which would be used to produce a flow of gas at high pressure and temperature. To keep the reactor's temperature to within manageable limits, it has to be cooled, and this can be done in several ways. It can be constructed with air-cooling passages, or made so that a coolant can be pumped through, and the heat dissipated in a heat exchanger—similar in principle to a car's radiator. The evolution of a satisfactory coolant is, however, a major problem in itself—liquid sodium being one of several possible solutions that have been investigated.

A third possibility is the use of a steam-turbine system in which water under pressure is used as a coolant. An advantage of this principle is that the whole power of the engine can be used for propulsion. Pressure is removed from the water when it has done its job cooling the reactor and the resultant steam is used to power the turbine before being condensed and passed back, under pressure, through the reactor again.

Atomic-powered rocket engines would be less complicated. The coolant might be pumped through the reactor and out of the tailpipe, the range of the aircraft or missile being determined by the amount of coolant carried.

Another problem associated with atomic aircraft engines is the shielding of the crew and passengers from radioactivity emitted by the reactor. This necessitates a metal screen of great thickness. If lead were used—this being one of the most effective metals—a thickness of 2 feet would be necessary, thus incurring a tremendous weight penalty.

Other problems include the crash risk—radioactivity could be scattered over a wide area—and landing weight. On gas turbine and piston-engined aircraft, the fuel consumed in flight reduces the aircraft's landing weight, but this does not apply to an atomic-powered aeroplane. Undercarriage and structure would have to be stressed for landings at maximum weight and greater speed. But a long-range conventional aircraft designed to carry 100,000 lb. of fuel (enough for perhaps 5500 miles) could travel the same distance with 0·05 lb. of uranium 235, the fuel for an atomic engine. Indeed, one pound of U235 could supply as much heat as the burning of more than 1½ million gallons of petrol. Thus, atomic-powered aircraft would have almost unlimited range and the first examples may therefore be large bombers, ocean-patrol flying boats (perhaps on the lines of the model exhibited by Saunders-Roe at last year's SBAC Exhibition) and transports.

It may be that Rolls-Royce has already gone far in solving these and other problems associated with atomic aero-engines.

THE AUTOMATIC COUNTING OF ROAD TRAFFIC

G. CHARLESWORTH, B.Sc., Ph.D., F.Inst.P., and J. A. HILLIER, B.Sc.

Road Research Laboratory, Department of Scientific and Industrial Research

Planning roads, investigating traffic congestion and studying accidents all require information about the amount of traffic using the roads. A common method of obtaining this information is to use enumerators at the side of the road to take a census of traffic. This procedure is necessary where vehicles are to be classified into categories, but for many purposes it is sufficient to know the total number of vehicles passing along the road. Such data can be obtained at a relatively small expense by automatic counting devices supplemented with occasional sample counts using enumerators.

Automatic traffic counters consist essentially of some device for detecting the passage of a vehicle. Detectors are of three main types (*a*) a magnetic loop placed below the road surface, (*b*) a beam of light, focused across the road on a photo-electric cell, (*c*) a tube on, or a pad in, the road surface, across the road. Of these devices, the last type, employing a rubber tube stretched across the road, is the most widely used, being portable and relatively simple. It first came into use in the U.S.A., but since the war traffic counters employing this principle have been manufactured and used in Great Britain. In the counter now used, a detector consisting of a length of rubber tubing of about ½ inch in diameter is stretched across the road and secured to it at 3-feet intervals by clips made of canvas and brass, nailed to the road with specially hardened steel nails. The passage of a vehicle over the detector causes a pulse of air to travel along the tube, and this deflects a diaphragm switch which then closes a circuit through an electrically operated counter. The diaphragm unit and counter are housed in a box at the side of the road. A typical installation of tube and counter is shown in Fig. 2. Counters of this sort can be adjusted to exclude bicycles from their totals but they cannot distinguish between types of motor vehicles. The detector tube is placed at right angles to the flow of traffic and the instrument then counts axles (not vehicles). The relative numbers of two-axle and multi-axle vehicles are estimated from sample counts made at intervals by enumerators. Tubes are not installed where standing vehicles are to be expected or near intersections where there is turning traffic.

The instrument shown in Fig. 2 is a simple accumulating type. When totals are required over specified intervals the counter has to be read at the required

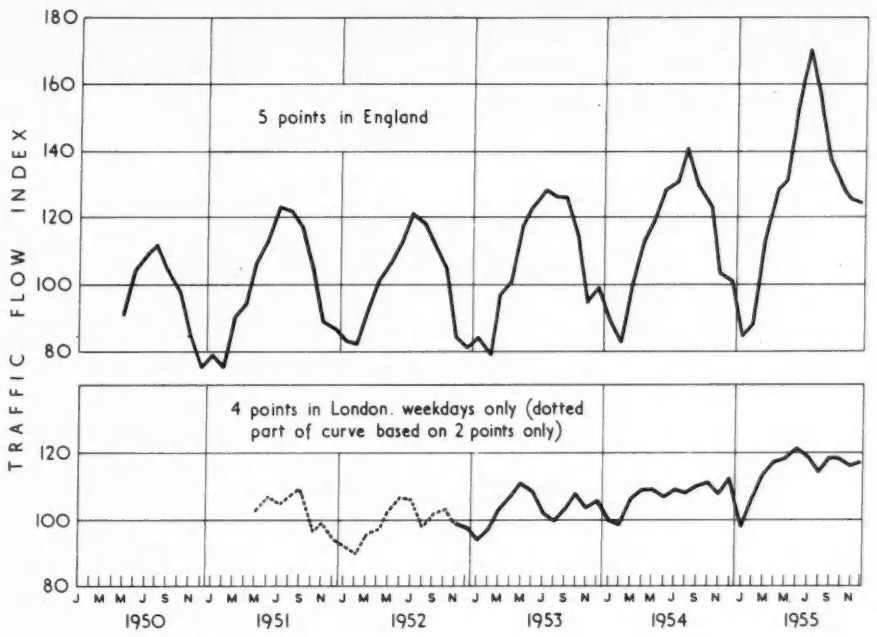

FIG. 1. Values of traffic flow indices for England and for London (weekdays only) 1951=100.

times. Other counters are, however, available which record automatically the total of vehicles passing, for example, every hour.

The simple accumulating counters are powered by 12-volt dry-cell lantern batteries which last for two to three months. The more complex hourly recording type use a 6-volt lead-acid battery which requires recharging every two weeks. The clock in these recording counters has to be wound once a week.

Unavoidable errors arise due to coincidence of vehicles on the detector tube, but correction factors can be readily applied depending on the traffic flow which is being counted. The counters are accurate to a few per cent at flows of several hundred vehicles per hour. Some attempted counts fail due to breakdowns such as the mechanical failure of the counters, or punctures in the detector tubes, so when planning a series of counts, an allowance of 10–20% is made for possible failures.

The Laboratory has been using automatic counters for many years to study trends in vehicle mileage. Fig. 1 shows results obtained at four points in London and at five points in other parts of the country. These clearly illustrate the seasonal variations in traffic and the growth which has been taking place over the years. It is interesting to note that the growth in London has been lower than that outside. These counts so far have been made only at a few points, but a series of counts has now been started at fifty points on classified roads spread throughout the country: it is hoped that these will give a more reliable account of traffic trends in the country as a whole.

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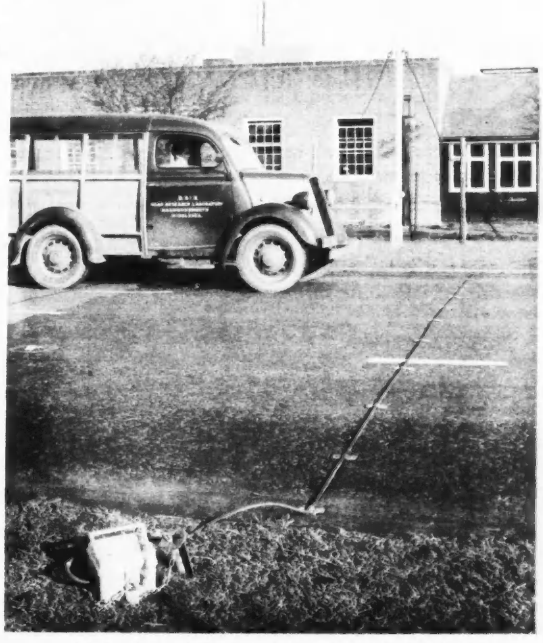

FIG. 2. A typical automatic counter installed for experimental purposes on a road outside the DSIR Road Research Laboratory. A large number of these counters can now be seen in the streets of London.

THE ARTIFICIAL EARTH SATELLITE

PROF. S. F. SINGER

Physics Department, University of Maryland College Park, Maryland

Professor S. F. Singer has engaged in high-altitude research since 1946 when the first V-2 rockets became available. He later participated in the first Aerobee rocket firings and is now engaged in upper atmosphere research using very simple inexpensive rockets which can be launched from aircraft as well as from the ground.

His interest in artificial satellites stems from his three-year stay in Great Britain as a scientific liaison officer attached to the U.S. Embassy and his association with the British Interplanetary Society. He is best known for proposing concrete applications for a so-called minimum satellite, unmanned but instrumented, and for developing a specific prototype design, the MOUSE. He wrote and proposed the resolutions concerning artificial satellites which were adopted by various international scientific bodies in the summer of 1954.

Nearly 300 years ago Newton laid down the form of the science of celestial mechanics. Now suddenly, technological advances in only the last twenty years have made it possible for us to become more than just passive bystanders watching these laws in operation. Thanks to developments in rocket propulsion, and thanks to the clear statement of its scientific justification, a satellite programme has sprung into operation for the purpose of investigating the upper atmosphere and the nature of extra-terrestrial radiations. For the first time, also, man is going to be permitted to apply these laws of celestial mechanics in any way he chooses. We will, so to speak, choose a celestial orbit for a small body, this orbit to suit our convenience, our ideas of utility, and to suit such commonplace factors as cost. This will be the orbit of our space satellite. There is no choice, however, as far as the celestial mechanics features of the orbit are concerned. It will be elliptical, with the earth's centre at one of the foci of the ellipse. Although the aim will be to make the orbit as near circular as possible, a perfect circular orbit is extremely unlikely. We do have a choice, however, about the plane of the orbit. We can place it in any direction we please, subject only to the condition that the plane of the orbit contain the centre of the earth. For example, we could place the orbit to contain the equator, or to contain both poles (a so-called polar orbit), or to be inclined to the equator at any angle we choose between zero and 90°. We are also free, within practical and technical limitations, to choose the size of the orbit. It seems likely that at the present stage of rocket development we will not be able to achieve more than an orbit of approximately 300 miles altitude, although relatively little extra energy would be needed for a higher altitude. On a 300-mile orbit the satellite travels with a velocity of about five miles per second and makes the circuit about the earth in just over ninety minutes. (See Fig. 1.)

To achieve the high orbital velocity, and to confine it to a very small angular tolerance, is no mean technical problem. Even achieving the necessary speed demands the utmost in rocket propulsion techniques. In order to transfer as much as possible of the reaction momentum to the satellite, the weight of the rocket structure must be kept small. There are limitations to this because rocket motors, propellant tanks, all require a certain mass. In practice, therefore, we employ the so-called step-rocket principle in which the size of the rocket is diminished in steps. We start with a very large rocket,

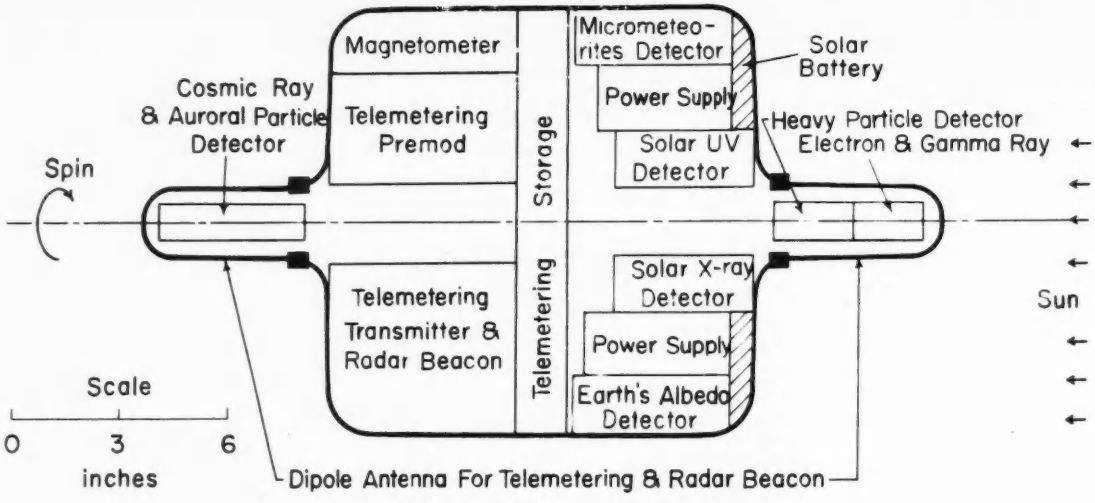

FIG. 1. MOUSE Satellite. Diagram of gyroscopic stabilisation scheme, solar power supply, and astrophysical instrumentation.

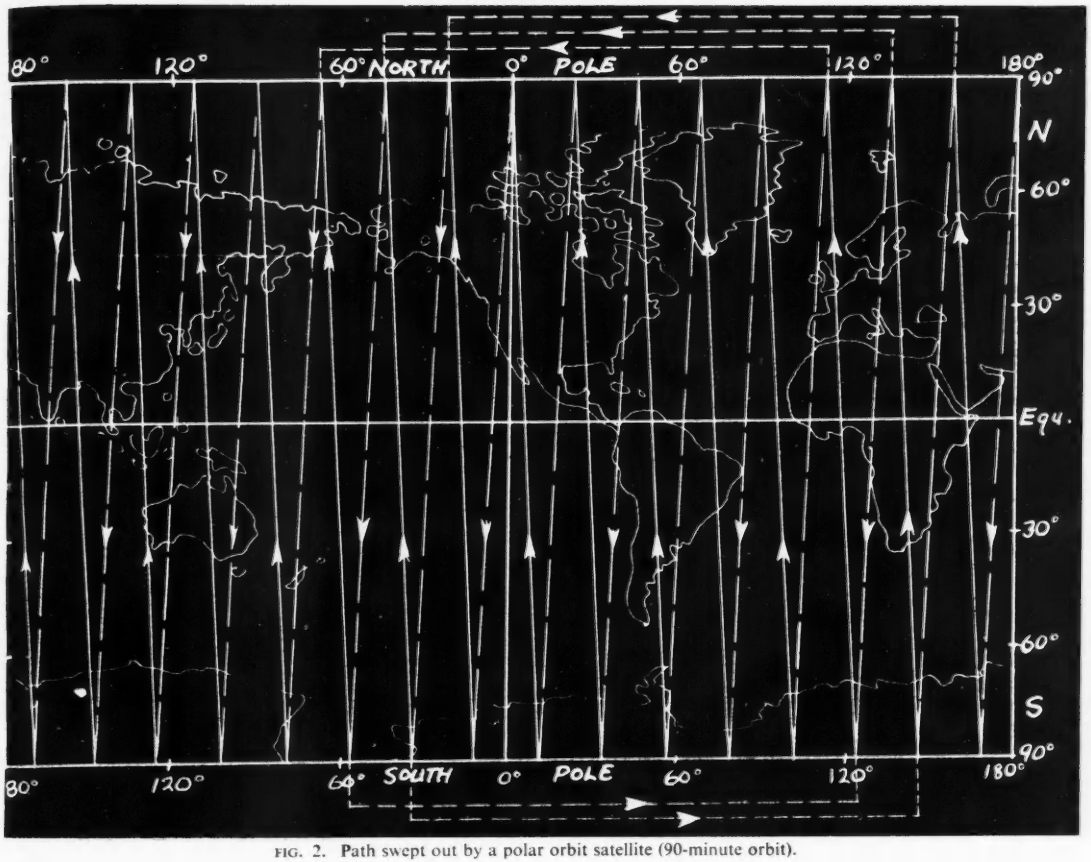

FIG. 2. Path swept out by a polar orbit satellite (90-minute orbit).

on top of which sits a medium-sized one, on top of which sits a small one. This last stage contains the satellite itself. Now, after the first stage has burned out, the second stage will start to fire and increase the velocity by adding its contribution and tilting the trajectory farther from the vertical. The final stage then adds the last required amount of speed; it must be designed so that at the end of its burning the satellite velocity has the orbital value and is directed along the horizontal.

The orbit, its size, shape and inclination, is completely controlled by the value and direction of the satellite's velocity at the instant of the last rocket's burnout. After that, only the earth's gravitational field affects the satellite, constraining it to follow its elliptical orbit. In addition to the earth's field there are many smaller forces which produce the so-called orbit perturbations. The gravitational effects of the sun and the moon are quite minute. But at this close distance to the earth, the shape of the earth itself and irregularities on the surface of the earth play an important part in determining the exact orbit at each instance. The main influence is the non-spherical shape of the earth, the fact that due to its rotation the earth possesses an equatorial bulge and a flattening at the poles. In an inclined satellite orbit the effect of the equatorial bulge is like that of a precessing torque on a gyroscope. Therefore, without changing its inclination angle to the equator, the orbital plane will rotate slowly so that its nodes regress. In addition to the gravitational influences there are minute effects on the satellite orbit, due to particles of meteoric dust and even light pressure. But by far the most important effect, at least for the initial satellites which are still within the reaches of the earth's atmosphere, is atmospheric friction. Even at 200–300 miles the atmosphere, although a better vacuum than we can produce at sea-level, contains an appreciable number of molecules; in each separate impact with an atmospheric molecule the satellite loses some of its energy and the effect of this loss will be to change the orbit to one of lower energy. (See Fig. 2.)

If the satellite orbit is initially an elongated ellipse, we may distinguish two points of special significance: the apogee, the point of farthest approach, and the perigee, the point of closest approach, to the earth. Whenever the satellite goes through the perigee, the energy loss due to atmospheric friction is particularly severe. We have calculated this energy loss and its effect on the shape of the orbit, and find that the orbit will soon change from

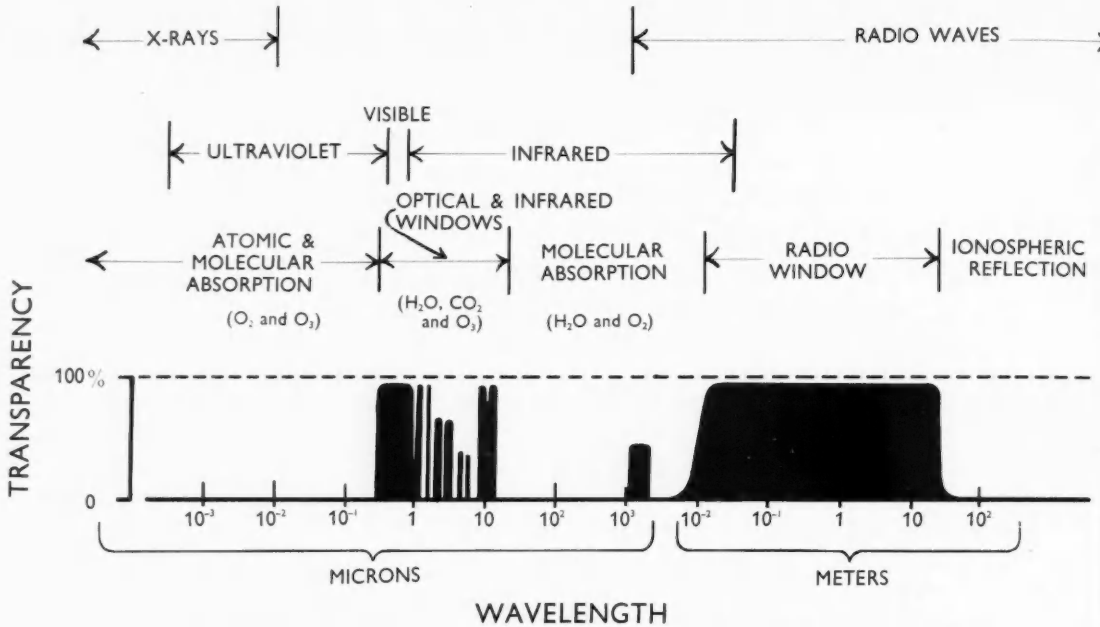

FIG. 3. Transparency of earth's atmosphere for electromagnetic radiations. With the exception of the visible region, a portion of the radio spectrum, and some narrow windows in the infra-red, the atmosphere is not transparent to electromagnetic waves. They must be observed at high altitudes, the minimum altitude depending on the wave-length of the radiation to be measured.

an elongated ellipse towards a circle. Of course, by the time the orbit becomes nearly circular, the energy losses will occur over a larger portion of the orbit; this will first gradually and then more rapidly shrink the orbit until finally the satellite hurtles to earth. In the last few seconds the atmospheric heating becomes so severe that the satellite structure is weakened to the point of break-up; the fragments of the satellite may partially vaporise before arriving on the earth. The "life-time" of the satellite depends critically on the perigee and apogee altitudes of the initial orbit which in turn depend on the initial errors in the launching velocity. We have calculated that if the satellite is launched at 300 miles altitude, the launching (or burn-out) velocity must be held to within 1% of the circular velocity and the angular error to within one or two degrees from horizontal in order to achieve a satellite orbit which lasts for more than a few hours. Of course, if by proper control of the rockets the satellite's perigee can be held high enough above earth so that the atmospheric losses are small, the satellite survives for a long time: a life-time of as much as forty days at an altitude of 200 miles, about three years at 300 miles.

Fascinating as the "planetary engineering" aspects of the satellite project may be, its real usefulness lies in the application to problems of the upper atmosphere and extra-terrestrial radiations. This is the reason why the International Scientific Radio Union's Upper Atmosphere Commission under Sir Edward Appleton was quick to realise the potential benefits of such a satellite for ionospheric studies and passed in August 1954 the first international resolution endorsing the establishment of a satellite. A few weeks later in Rome the International Union of Geodesy and Geophysics, and then the Special Committee for the International Geophysical Year, similarly endorsed carefully worded resolutions about applying satellites to geophysical problems.

Most of the advantages gained by a satellite are similar in principle to the advantages of high-altitude sounding rockets; by going above the appreciable atmosphere it is possible to peek at radiations and particles coming in from outer space which are normally stopped or certainly modified by the atmosphere. Reference to Fig. 3 and Fig. 4 will make it clear that the atmosphere really only transmits electromagnetic radiation in the visible region of the optical window, and in the so-called radio window. Hence, all our knowledge about outer space comes from observing astronomical objects in the visible region and, through the recent developments of radio-astronomy, also in the radio region. This includes the sun, but the sun is such a powerful star, at least in relation to the earth because of its close proximity, that we can observe some of its invisible radiations indirectly. We know of the presence of solar ultraviolet through the existence of the ionosphere, the ionised region between 50 and 200 miles which reflects radio waves and allows us to carry out long-distance communications. But unfortunately we have no means of gaining

direct information about the solar ultraviolet, and the occasional rocket experiments have given us only a very sketchy view of what must be tremendous time variations of the solar radiation. It is fair to regard the sun in the ultraviolet, as W. R. Piggott puts it, as a variable star and we can see its variability reflected in the variable state of the ionosphere. Since, however, an exact study depends on knowing in detail the spectrum of the sun and its variation, we are still very much in the dark about the precise causal connexions between solar radiation and the ionosphere. This study certainly promises to become one of the most important applications of an instrumented earth satellite. With specially designed photocells or photon Geiger counters we will observe different portions of the sun's spectrum, record the number of photons and telemeter the information back to earth, there to be compared with ionospheric observations carried on from the ground. There is no doubt that such observations will give tremendous impetus to the already dynamic science of the ionosphere.

Even a cursory examination of Fig. 4 shows that none of the extra-terrestrial particles can arrive near sea-level, at least not in their original form. Even the highly energetic cosmic rays are changed into secondary particles. The primaries are stopped high in the atmosphere and produce nuclear disintegrations which result in the formation of secondary particles; these are then detected in the lower altitudes. Of course, it would be possible to observe the primary cosmic rays in balloons, as has been done at Bristol University and elsewhere. But here appears another great advantage of a satellite vehicle, an advantage which it possesses even over the high-altitude sounding rocket. For aside from the ability of staying up for extended periods of time, measured in days or even weeks as compared to the few minutes of a high-altitude rocket, a satellite is by definition a globe-circling body. We can make it circle the globe over the poles and therefore we can make it traverse all latitudes. Here then we have a chance to study the influence of the earth's magnetic field on the primary cosmic rays; for by allowing the earth's field to act as a magnetic spectrometer, we can analyse the cosmic rays according to their energy and determine this energy distribution from minute to minute. This type of information is of the greatest value in our attempts to grapple with the problem of the origin of the cosmic rays. We could, for example, examine precisely what happens to the primary energy spectrum during the times when the cosmic ray intensity mysteriously drops, as has been observed during magnetic storms, and we could even hope to study the rare events when the cosmic ray intensity rises tremendously during periods of intense solar activity.

Little can be said at the moment about micro-meteorites, the extremely small pieces of dust which enter our atmosphere in such large quantities. They

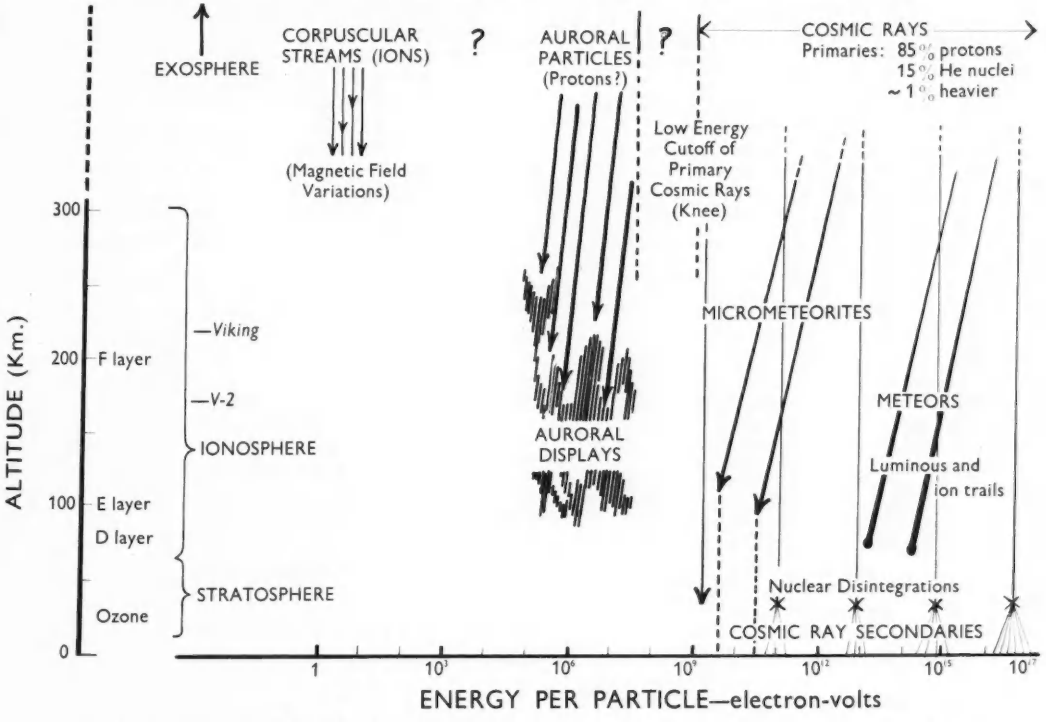

FIG. 4. Penetration of particles into the atmosphere. Particles arriving from outer space are stopped or modified by the atmosphere and must, therefore, be observed above the atmosphere.

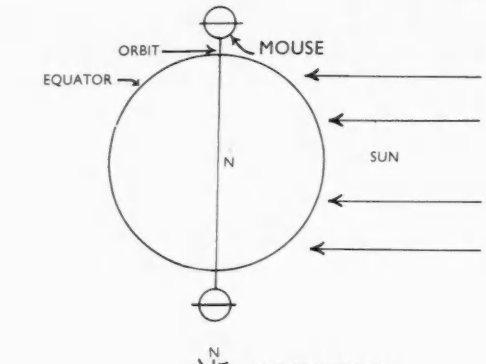

FIG. 5. Possible orbits for the unmanned satellite.

produce no directly observable results. Even less can be said about auroral particles, for although their results are quite spectacular, their nature and origin is essentially uncertain. The satellite can be employed to aid in the measurement of both of these phenomena.

Going on to even lower energy particles, we suspect their existence in clouds which are shot out from the sun in what appear to be puffs or streams coming from regions of solar excitation. These streams of particles or corpuscles are ionised and produce in their approach to the earth very remarkable effects on magnetic field-measuring devices at sea-level. We may think of these streams of approaching gas as producing a pressure on the earth's magnetic field which is transmitted to sea-level and results in observed field changes. However, this transmission takes place through the conducting ionosphere. By placing a magnetometer above the ionosphere and comparing it with a similar instrument on the ground one may derive an important clue about the position of the currents which produce these magnetic field changes. Some rocket experiments have already located the ionospheric current, which was first predicted by Balfour Stewart in 1882, by firing a magnetometer through it; but we suspect that the current which flows during magnetic storms is largely located far beyond the earth in a ring current first postulated by Störmer and investigated carefully by Chapman, Ferraro and others. (See Figs. 5 and 6.)

Looked at from this point of view, the satellite certainly appears as the indispensable instrument for geophysical and certain astrophysical studies. It is clear, also, why it is not necessary to obtain a precisely defined altitude or precisely defined orbit for the satellite. As long as it remains above the appreciable atmosphere it will do its job of recording radiations very nicely. Of course, there are many problems to be solved in order to instrument a satellite properly. Some of the outstanding ones are the problem of orienting it in space and the problem of supplying it with electric power to operate the transmitter and other instrumentation. The so-called MOUSE satellite (Minimum Orbital Unmanned Satellite of the Earth) is an attempt to meet these problems of orientation and power. In this proposal it is intended to spin the satellite before take-off about a horizontal axis arranged to point at the sun. The satellite is mounted in gimbals, and at its release from the last rocket stage it will remain spinning about this same axis which is still pointing at the sun. The MOUSE orbit is arranged to pass over the poles and to be in a plane perpendicular to the sun-earth line. In this manner the horizontal axis can be used as a transmitting antenna and can also house certain instrumentation which should be kept away from the bulk of the satellite. Instruments which are to watch the sun can now be placed in their proper location to point at the sun, and the solar energy falling on the satellite can be converted directly into electricity using the silicon solar batteries recently developed by the Bell Telephone Laboratories.

But even without instrumentation a satellite would still be useful. Just by noting its orbit and any changes of the orbital elements with time it may be possible to deduce the atmospheric densities at very high altitudes, something which is not feasible by other methods. Clearly, to accomplish this aim the satellite must be visible optically from the ground. This may be a difficult problem although calculations show that a 21-inch diameter sphere painted a flat white would be visible to the naked eye as a star of sixth magnitude, provided it is properly located with respect to the observer and the sun. But in order to discern the satellite against the sky it will be necessary to make the observations when the sun has dropped below the horizon and the sky is nearly dark. Unfortunately, when the sun is too far

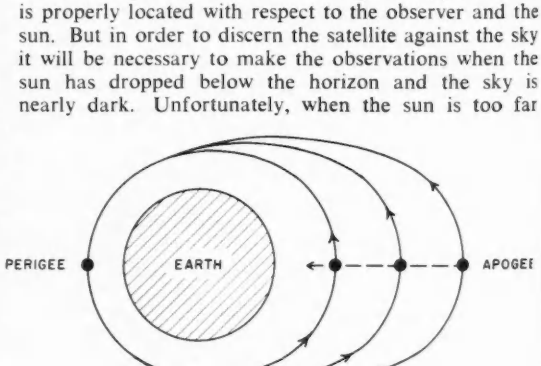

FIG. 6. Decrease of eccentricity of elliptical orbit due to drag at perigee.

below the horizon, the satellite itself will be in the earth's shadow and hence invisible.

Some of the observations possible with even the smallest satellites may have considerable economic value. I am referring to observations of the reflected sunlight from the earth and other meteorological measurements. A simple instrument, for example, a photocell, located in a spin-oriented satellite like the MOUSE could get a continuous picture of the earth's albedo on a global scale and therefore measure the solar energy input at every point of the earth's surface. More than that it could locate large cloud areas and report on their development and motion from hour to hour. Such observations would be of inestimable value to meteorologists concerned with the large-scale motions of the atmosphere and with calculations of heat balance and energy transfer in the atmosphere. These observations may well allow us to gain a clearer picture into solar influences on the earth's weather and lead to the possibility of making more certain long-range predictions of weather and of climatic trends.

Certainly the results of the earth satellite research promise to stimulate all of the earth sciences and provide a fitting complement to the many observations which are to be carried out on a global scale by scientific groups all over the world during the International Geophysical Year. (See Fig. 7.)

Beyond this, the earth satellite project will project mankind into a new dimension and may well mark the first step into space flight. For surely a successful programme of instrumented minimum satellites must precede the development of larger earth satellites with their more detailed and important applications, and the development of vehicles capable of carrying man himself into space. In an age where technological progress on a rapid scale has served to deepen the tensions between nations, this prospect of a common scientific endeavour may lift mankind above the frightening prospects of global warfare.

FIG. 7. Dr. Joseph Kaplan, chairman of the U.S. National Committee for the International Geophysical Year, looks on as Dr. Athelstan Spilhaus, an executive committee member, inscribes the path of the proposed earth satellite on a globe at the University of Michigan

INTERNATIONAL GEOPHYSICAL YEAR: ARCTIC AND ANTARCTIC NEWS

The Polar ship *Kista Dan*, with the Australian Antarctic Expedition on board, has been held up by tightly packed ice-floes in the Davis Sea, on her westward journey to the permanent Australian base at Mawson on the Antarctic mainland.

The leader of the expedition, Mr. P. G. Law, reported that the *Kista Dan* encountered a severe blizzard on February 1. The ship's bows were wedged into a large ice-floe and her engines kept running to maintain her position. The weather improved on February 3 and 4, and on February 5 an effort was made to manœuvre the ship to the open water only a few miles ahead, but in five hours the ship advanced only 100 yards, and the attempt was abandoned. Since then the *Kista Dan* has freed herself and proceeded on her way.

The first contact between Australian and Russian Antarctic expeditions has been reported to the Australian Minister for External Affairs, Mr. Casey.

Mr. P. G. Law reported a friendly meeting with the Russian advance party which, in preparation for the International Geophysical Year, has set up a scientific base at Haswell Island. The meeting took place when Australian scientists inspected Russian installations and equipment.

Another drifting research station, North Pole No. 6, will be set up in the Central Polar Basin in the spring of this year. It is intended to establish it at the spot where North Pole No. 2 station ended its drift—at latitude 80° and longitude 180°. North Pole Stations Nos. 4 and 5 will continue their work.

Research in the areas of the Northern Sea Route will include complex oceanological expeditions to the Greenland Sea.

An airborne Arctic expedition to carry out short-term research on the ice is also planned for this year.

PHOTOSYNTHESIS AND FOOD PRODUCTION

PROF. HUGH NICOL

Chemistry Department, The West of Scotland Agricultural College, Glasgow

"Insert your chopstick in the solid meat, Tso Paik. What have we got to *do*?"
"Putting aside these gems of philosophical profundity, Benign, the nature of your submission is neither palatable nor light."

—Ernest Bramah: *Kai Lung unrolls his mat*: The story of Wan and the Remarkable Shrub.

Though the belief in an expanding domain for man that characterised the latter half of last century is far from dead, it is becoming subdued; questions are creeping in; and optimism is widely tempered with doubt about the control of use of "atomic" energy.

Probably, most people would agree that the prospect for food is cardinal to any assessment of the future. Yet, agreement about the importance of food is not matched by seriousness of discussions of its prospects. What passes for informed comment about food-production on a world scale is almost entirely fanciful. It is remarkable that the simple and definite principles which pertain to food production have gone without acknowledgment by almost everyone who has written a book or substantial article, or made a presidential address, about the present and possible situation for food. What is still more remarkable is that such assessments have been vitiated by serious errors because the authors have scarcely had contact with reality about their chosen topic.

The ideas promulgated by William Crookes in 1898 about nitrogen form part of this mythos; yet it can be seen that Crookes was wrong in every material particular of his excursion into agricultural science. The principle, published by Lawes and Gilbert in 1900, that a characteristic of nitrogenous fertilisers is to increase non-nitrogenous constituents of (mature) plants was founded on many years of observation and has been confirmed by practice everywhere. It forms no part of popular discussion of food problems.

More recently, the fallacy has been nourished that plant growth and food production can be assured, even increased, by greater reliance on photosynthesis. Since this ignores the indispensable role of nitrogen, the proposition is untenable. It can be made to seem plausible only by appeal to bad science, and by ignoring facts which would make for consistency. When a Nobel laureate in physics gives the proposition his blessing by quoting it in a book about the future, is the implication that he does not regard as important the distinction between heats of combustion and formation: or just that he has not bothered to look into the assumptions?

Most of the disquisitions on future trends have been written by physicists and engineers whose attention has been so greatly occupied by considerations of external energy that the thermodynamics of food have had scant or no attention; also, the functions of fuel as a source of *substances*—chemicals and food—have been substantially ignored by those writers. No chemist has been so incautious as to produce a survey with a corresponding refusal to acknowledge physical energy; yet the general lack of insight into food shows that that not unimportant matter has been conspicuously left to amateurs.

There is a grave shortcoming in knowledge of applied biology. A survey of the surveys does show how remote from the world's published thought are concepts ordinary in agricultural chemistry. The discipline of soil chemistry and soil microbiology will be salutary in discussing the future: as, for example, in terms of what can be got out of photosynthetic energy.

By "photosynthesis" may be understood, for the present, an appeal to green plants to capture solar energy. Among the projects meant to increase the utilised fraction of solar energy, with the aim of producing more food or fuel, those stand out which are based on intensive cultivation of microscopic fresh-water algae. Algae selected for this purpose include the green (type: *Chlorella* spp.; fresh-water inhabitants) and the blue-green (type: *Nostoc* spp.; soil-dwellers). Both possess chlorophyll, and engage in photosynthesis. Some of the blue-green algae share with certain other micro-organisms the ability to utilise atmospheric nitrogen directly, so as to build it up into protein and other nitrogenous compounds.

Excepting some photosynthetic bacteria, the blue-green algae are unique in being able to "fix" both carbon and nitrogen direct from gases prominent in ordinary air. For that reason, the blue-green algae are attractive subjects for cultivation—since in theory they require no bought source of nitrogen such as nitrate; but they are difficult to grow in quantity. Research with blue-green algae is proceeding. The blue-green algae can nevertheless be practically dismissed from this article because cultivation of microscopic green algae (especially species of *Chlorella*) has had the most attention and exuberant publicity.

NITROGEN SUPPLY

Green algae are plants. Like other botanists and plant physiologists, students of the growth processes of *Chlorella* and other green algae are aware of the necessity for supplying compounds of nitrogen and other nutrient elements, besides carbon dioxide and water. Many writers about *Chlorella* and other plants unable to "fix" atmospheric nitrogen take the nitrogen supply of their organisms for granted, and do not discuss its origins. John Burlew, the editor of a substantial book on algal culture, wrote: "Land area is not the only requirement for the large-scale culture of algae. For every pound of dry algae harvested, a minimum of two pounds of carbon dioxide and one-twelfth pound of combined nitrogen are required. The latter can be

obtained from the atmosphere by fixation processes that have been in commercial use for many years. Carbon dioxide is also abundantly present in the atmosphere; but its concentration must be increased several-fold before it can be used in the forced feeding of algae. How to do this cheaply is an unsolved problem. Fortunately, there are more concentrated sources of carbon dioxide that can be used for a long time to come."

This casual treatment of the nitrogen question is an example of leaving fuel out of an important reckoning. It is a huge paradox that the photosynthesis enthusiasts, who are among the foremost in pointing out the need for more energy, should be so careless of the implications for stored energy inherent in their proposals.

The gravity of the fuel component of this problem can be readily seen by following up another idea in the same editorial. "Assuming [Burlew wrote] that half the per capita requirement of 65 grams of protein a day was to be obtained from algae, the total area required for algal culture would be little less than a million acres for the present world population. This is such a relatively small area that we may conclude that the introduction of algal culture need not displace existing agricultural crops."

Burlew's figure of one-twelfth pound of nitrogen per pound of dry algae corresponds to about 50% of protein when the nitrogen percentage of protein is taken as sixteen. To fix a ton of atmospheric nitrogen by the usual commercial processes requires the equivalent of five tons of coal; the fuel requirement is smaller when the synthetic fixation starts from natural gas, but that is not so widely available as coal. A rough and adjustable calculation* shows that, to meet Burlew's estimate, some 25 million tons of coal, or its fuel equivalent, would need to be consumed every year. That assumes that the algal protein is all eaten directly by man, and that its digestibility, like assimilation of the synthetically fixed nitrogen by algae, is complete.

If digestibility of algal protein is 50%, the fuel requirement might be doubled. But who except a few experimenters would eat the stuff? It has been suggested that the algal mass should be used as animal fodder. That use would entail a further factor (say, four) to cover losses in conversion to meat, milk and eggs. So, in spite of—or, rather, because of—Old Sol's organised efforts over an area of some 1400 square miles, the world might be eating every year about as much coal as Britain produces.

That would be far from the end of the fuel demands consequent on algal culture. There would be fuel for transparent covers, concrete and other structural features of the apparatus; for other algal nutrients than nitrogen; and for fertilisers in the agricultural adjustments inevitably arising if leguminous crops (which seem to be relatively effective in converting appropriate fuel, notably sulphur, into protein) were to be displaced by algal fodder.

*The calculation may be given in "order" form: 10^2 (grams of protein) $\times$ 3.10^2 (days) $\times$ $\frac{1}{2}.2.10^9$ (half population) $\times$ 5 (grams per gram nitrogen fixed)/6·25 (nitrogen factor) $\times$ 10^6 (gram per ton) $= 1{\cdot}5.10^{14}/6{\cdot}25.10^6 = \frac{1}{4}.10^8$ tons of coal per annum.

The idea is difficult to follow. It suggests that the advocates of intensive appeal to the contemporary energy of the sun are dealing in moonshine instead.

Scientists ought to pay attention to the wider aspects of foods, including agricultural implications and the weighty matter of acceptability. Resistance to unfamiliar foods is extremely strong. Outstanding examples are: the refusal of whale meat by Britons during the years of food scarcity after the last war—though whale meat is real meat and *almost* indistinguishable from beef; the failure of the nutritionally sound food-yeast scheme in the West Indies; the refusal of unfamiliar grain by famine-stricken people in the East. Microscopic algae have an unfamiliar and not very pleasant taste; however, that point now has small importance.

THERMOCHEMICAL CONSIDERATIONS

For several years, authors such as those editing, and contributing to *Algal Culture* and *Solar Energy Research*, seem to have based their estimates of energy and calorific values, in respect of algae, exclusively on heats of combustion of carbonaceous constituents. In 1949 Spoehr and Milner of the Carnegie Institution of Washington brought to notice what they called the R-value. This was part of the Institution's work with *Chlorella*; the R-value was calculated as a function of the percentages of carbon, hydrogen and oxygen in algal or other carbon-containing compound or tissue.

The R-value grades from 100 in methane to zero in carbon dioxide. Nitrogen was taken into account only for deduction, so as to obtain the oxygen percentage. Sulphur and phosphorus were excluded, and need no comment here. The authors wrote in their paper: "The degree of reduction is designated the R-value; it is proportional to the heat of combustion and is an expression of the energy content of the material." The R-value gives no hint about heats of formation from elements.

The absence of nitrogen from the formula for R-value neither justifies nor explains the recurring oversights about nitrogen in plant growth. These omissions would be fatal to the dogma that any kind of energy from additional fuel or food can be obtained by photosynthesis alone—even if the appeal to mere photosynthesis were not *a priori* so clearly untenable.

An argument founded on heats of combustion of photosynthetic plant products could be justified only if a source of assimilable nitrogen were as freely provided as current solar energy is; or if nitrogen in the cycle of nutrient, plant and soil were to be recoverable and reusable with perfect thermodynamic efficiency. In comparison, a search for perpetual motion seems almost reasonable.

Even by those who overlook the fuel requirements for nutrients it is now conceded that algae cannot economically be grown to produce fuel. It has been estimated, by a member of a United States firm of industrial consultants, that 12,500 pounds of dry algae would be equivalent to about 5 tons of coal. That estimate of a roughly ton-for-ton equivalence is made purely from heats of combustion. Yet, if containing only 35% of protein, *Chlorella* would barely "wash its

face" in energy needed for nutrients other than carbon dioxide.

It may be added that from every point of view a highly reduced fuel poor in nitrogen is preferable to one rich in protein—such as an alga with the 50% of protein so often quoted by enthusiasts about *Chlorella*.

Instead of burning *Chlorella*, it has been proposed by R. L. Meier (a contributor to *Solar Energy Research*) that the algal mass should be submitted to anaerobic fermentation so as to use the resulting gas as fuel; the alga need not be dried. Such anaerobic fermentations and their products are well known, and are sometimes used at sewage works and elsewhere. The process does not seem to do well with substances very rich in nitrogen; otherwise, whatever the substance fermented, the gas usually consists mainly of methane and carbon dioxide, with only a trace of nitrogen compounds. Virtually all the nitrogen (if not released as gas) appears as a bacterial sludge. Meier overlooked the energy necessary to fix nitrogen as nitrate or other nitrogen compound assimilated by the algae; having quoted W. A. Barker about fuel value of the gas expected from *Chlorella*, Meier further ignored the heavy loss of that quondam algal nitrogen in sludge and denitrification products. (Barker seems to have been asked the wrong question or to have been inadequately informed about what was in the inquirer's mind; so he can scarcely be held to have been implicated in this.)

Other major inconsistencies have sprung from the astonishing phenomenon of failure to take nitrogen into account in discussions of what is called photosynthesis. Climactic was a remark of Burlew following a rough estimate of the possibilities of putting algae to meet "all the food and energy needs of the expected world population of 7 billions". About 11 million square miles, or "about 19 per cent of the land surface of the earth, is small enough so that one may think seriously of algal culture as a means of utilising solar energy on a day-by-day basis when all the coal, oil and fissionable materials will have been used up".

PHOTOSYNTHESIS IMPROPER

Part of the confusion lies in uses of the word "photosynthesis". Indeed, there may never have been a better instance of widespread error springing from incorrect adoption of a word. Strictly, the word should refer (in connexion with green plants, understood) only to a process performed by the green plant, or possibly by plastids containing chlorophyll, under the influence of appropriate lighting, whereby carbon dioxide is reduced with hydrogen derived from a simultaneous photosynthetic decomposition of water. Chlorophyll contains nitrogen and magnesium; so at least those two additional elements are essential though not taking part in the actual photosynthetic reactions.

The term "photosynthesis" is often used loosely to denote the whole set of processes whereby green plants build up all their organic substances and tissues from the products of photosynthesis proper, in conjunction with already formed, mainly inorganic, compounds of nitrogen, phosphorus, sulphur, magnesium and numerous other elements. That use and sense are legitimate, provided that a restricted anabolic meaning is understood, *and* that the sources and energetics of the nitrogen and other elements (besides carbon, hydrogen and oxygen in carbon dioxide and water) either do not enter into the immediate and possibly academic study, or are not lost from sight if they do.

This latter proviso is rarely acknowledged once the composition of plant nutrient solutions has been stated. Writers about the consequences of anabolic "photosynthesis" must be among the most forgetful of people in so thoroughly dismissing nitrogen from their thoughts whether they have experience of plant culture or not.

Whereas it may be convenient and unobjectionable to extend the meaning of the term "photosynthesis" so as to embrace, say, a quantum study of formation of amino acid in the green leaf or algal cell while the nitrogen supply is assumed, it is evidently dangerous to go further; and it becomes stultifying when plans are erected for feeding millions of people on such a basis.

It is illegitimate to extend the meaning of photosynthesis from plant anabolism to embrace soil metabolism also: as (in opening a discussion about capturing more solar energy) by giving a "reminder" to the effect that all energy on earth, whether as food or fuel, comes from the sun through photosynthesis. That becomes ironic if the commentator goes on to overlook what the role of nitrogen must have been, and still is, in making photosynthesis possible and real. How many do recall such a tremendous trifle?

Microscopic algae may be useful as a source of steroids or other material for chemical and pharmaceutical manufacture. That possibility has been discussed by M. J. Geoghegan of Imperial Chemical Industries Ltd., and has also been the subject of investigation by the University of Maryland. The reasonable implication then is that the nutrient price might be worth paying for a limited, specific advantage. In other respects a principal effect of recent invocations of solar energy may be just to redden some faces.

THE GENERAL PROBLEM

Most of my space has been devoted to green algae for the reason that fantastic claims for *Chlorella* have been widely disseminated without challenge. The ineluctable energetics of nitrogen (and other nutrient elements) apply with equal force to any kind of plant. Algal cultivation is merely one case or aspect of a general problem: the problem of producing food. No output of food, or of any other material derived from plants, that is as great as, or greater than, the present-day output, can be expected, unless fossil fuel is devoted to the purpose and to an extent at least as great as at present.

Since photosynthesis proper is concerned only with the elements carbon, hydrogen and oxygen, the element nitrogen is obviously out of court until it is brought in by some relationship both cogent and well sustained. No such exhibition seems to have been attempted by writers about applied photosynthesis. It may be instructive to examine further the belief that photosynthesis, in

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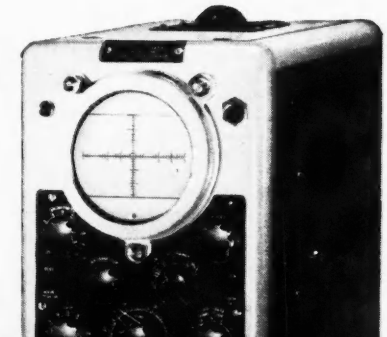

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some unspecified wide sense, can engender food additional to the approximate amount obtained up to about 1890: i.e. with a negligible use of fossil materials.

In view of the small proportion of incident solar energy now expressed in growth of wild and cultivated plants, it is superficially tempting to wonder whether that proportion can be increased by applying inventiveness. The prospect has allured many.

Estimates of the "efficiency" of conversion of contemporary solar energy into global plant produce vary a good deal; for the sake of argument the estimate can be taken that 1% of solar radiation falling on a given area is intercepted by all plants (or by all land plants, if that is preferred). Those who have publicised the problem of "putting the sun to work" have pointed to the great gain which would result from increasing that 1% to only 5%. This looks a modest enough aspiration, since 95% of the incident energy would still not be translated into plant material. Maybe the advocates of making the sun work harder on earth would be content with a doubling of the fraction absorbed in photosynthetic activities.

Since photosynthesis operates only upon carbon dioxide and water, multiplication of the energy utilised in photosynthesis can have one of only two results. Logically, the plants' content of carbonaceous substance and groups will be increased (say, doubled); thus the nitrogenous content (of what may be called "protein" for short) will be diluted to a half of the normal concentration. As the second alternative, an increased quantity of assimilable nitrogen imbued with a substantial heat of formation from elementary, atmospheric nitrogen must be found in some source external to the plant and its photosynthetic apparatus.

That outside source might be a solar furnace applied to nitrogen fixation; but the proponents of such devices have not yet shown them to be either practical or self-sustaining in respect of ores and fuel. As "outside" source, an additionally increased growth of legume nodule bacteria might supply the needed increment of combined nitrogen; but that newly exalted level of partnership of bacteria and leguminous host-plant could be kept up only by extra supplies of non-nitrogenous nutrients such as phosphate, potassium, calcium and sulphate, to make and transport which an unknown, but weighty, proportion of fuel and energy would have to be diverted.

Part of the insubstantiality of the "increased photosynthesis" idea comes because the dilemma of balance of nitrogen and carbon has not been recognised or even looked at. The advocates of more-photosynthesis-for-greater-food-supply have unanimously taken nitrogen supply for granted; and not a glance has been given to problems of metabolism of nitrogen in soil.

NUTRITIONAL BALANCE

It is abundantly evident that photosynthesis *per se* can do nothing to increase the supply of proteins, which are the most difficult of organic nutrients to produce for man, and have presumably always been a factor limiting population and amenity. If some new method were to be discovered to intensify the operation of the first alternative mentioned above, one practical result would be simply a great increase in carbohydrate and fat without protein to give the needed nutritional balance.

As a historical fact, such methods (though not very intensive) are known and have been used. The chief of them is the use of nitrogenous fertiliser for ordinary non-leguminous crops (it is uneconomical to apply it to legumes as a rule) together with potassium fertilisers for most crops. This leads primarily to production of sugar and starch and other non-protein aliment (Lawes and Gilbert's principle) which, on account of its lack of nutritive balance, cannot properly be called "food"; yet it entails a heavy fuel cost.

A similar result must be looked for from realisation of other prescriptions, such as growing hybrid or other field crops of varieties specially bred or adapted to utilise solar radiation more effectively; and, of course, all extra growth of crop beyond the natural level demands great use of earthy substances as well as of nitrogen. Unless the excess of fixed carbon could be used as fuel, the Utopian result of extra photosynthesis *sensu stricto* would be a wasteful embarrassment—not a benefit —from the food point of view. Some people are today embarrassed in just that manner by having too much wheat.

CARBON NITROGEN RATIO

Consideration of a potential large increase in output of carbohydrate and fat in inedible parts of plants raises a serious microbiological query. If the sun were to oblige by producing twice as much carbonaceous matter per unit of nitrogen, what would be the effect on the soil, and on the crops of subsequent seasons, of returning to the soil (or sea) such a mass of residues relatively poor in nitrogen? That question brings in the "carbon/nitrogen ratio" which is fundamental in the subject of aerobic decomposition belonging to good soils.

It may be sufficient to say that a doubled C/N ratio would considerably impede decomposition of plant remains. The sea might smell. Since the seasons will be unchanged, the *rate* of turnover of sea and soil nitrogen is decisive. The rate of decomposition of plant material could be restored to normal by adding nitrogen.

Cultivation of *Chlorella* with the aim of producing extra protein follows the second of the stated alternatives. Growth of green algae or of food-yeast or of any other young plant or young vegetable tissue unable to fix atmospheric nitrogen may be as much an exercise in converting inorganic or synthetic nitrogen into protein as it is an essay in photosynthesis. In *Chlorella* or in frequently cut pasture grass the high rate of output of protein from added nitrogen accompanies direct photosynthesis; in food-yeast and other non-photosynthesising organisms photosynthesis (of preformed sugar) is at a remove.

A PRINCIPLE OF IMPOTENCE

The suggestion imposes itself that the grand question about future supplies of food resolves itself into a demonstration of the impossibility of increasing plant growth by appeal to photosynthesis alone. It leads,

with equal importance, to the equilibration principle that no further augmentation of the plant-bacterial mass, and hence of the numbers of animals, can be hoped for without recourse to fossil reserves; and hence to the suggestion that, whatever use man proposes to make of fossil reserves of fuel in the near future, care should be taken to leave some of those reserves for feeding the generations to come.

As Sir Charles Darwin has indicated—on grounds not specifically concerned with food—we are now in a phase of social development that is subject to the inherent irreversibility of revolutions. Darwin's criterion applies to the Second Agricultural Revolution which took effect at about the turn of this century; for, although the relation of man to microbes, plants and animals is always an equilibrium state and therefore reversible, the present phase as it affects Europeans and Orientals cannot be reversed without strife and loss in numbers of people who live in our stage of development. The point of no return in our flight through time was passed approximately sixty years ago.

The notion that no further increase of the plant-bacterial mass can be attained without our making correspondingly deliberate (and, it may be, deliberated) incursions into stored natural reserves, and especially stocks of fuel, may possibly be added to the seven "principles of impotence" listed by Sir George Thomson. Thomson has pointed out that some scientific principles of high order and validity are concerned with what cannot be done. There could be no more foolish error than to suppose that science makes progress inevitable: the "more-food-from-more-photosynthesis" postulate is only a facet of that immature and false belief.

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LETTER TO THE EDITOR

THE SEA AS A CHEMICAL STORE

Sir,

The section of Dr. Gordon Cook's interesting article in your February 1956 number dealing with bromine from sea water contains some inaccuracies which I should like to be permitted to correct, and at the same time to add a few further facts which might be of interest to your readers.

The "floating factory", the s.s. *Ethyl*, was not a "factory", but combined a pilot plant experiment with a sea-water survey. The experiment was made in 1925 to demonstrate the practicability of extracting bromine from the sea, as it was foreseen that the potential demand for bromine for the anti-knock industry would outstrip the traditional sources of supply for this element. The process used involved the precipitation and separation of tri-bromo-aniline, which could then be treated to separate the bromine and to recover the aniline for re-use. A second large-scale experiment was carried out by the Dow Chemical Company, who built a pilot plant at Kure Beach in 1931 to try out an adaptation of a process they were successfully operating to extract bromine from strong brines. This process proved more economical than the tri-bromo-aniline process and a full-scale plant was built in 1933, which came into production early in 1934, with an initial capacity of 18,000 lb. per day, and was soon extended. A still larger plant was later built at Freeport in Texas and a peak war-time production of bromine of over 50,000 tons a year was reached in the United States in 1944. Since the war the production of bromine has been concentrated at Freeport and the use of the Kure Beach plant was discontinued in 1945.

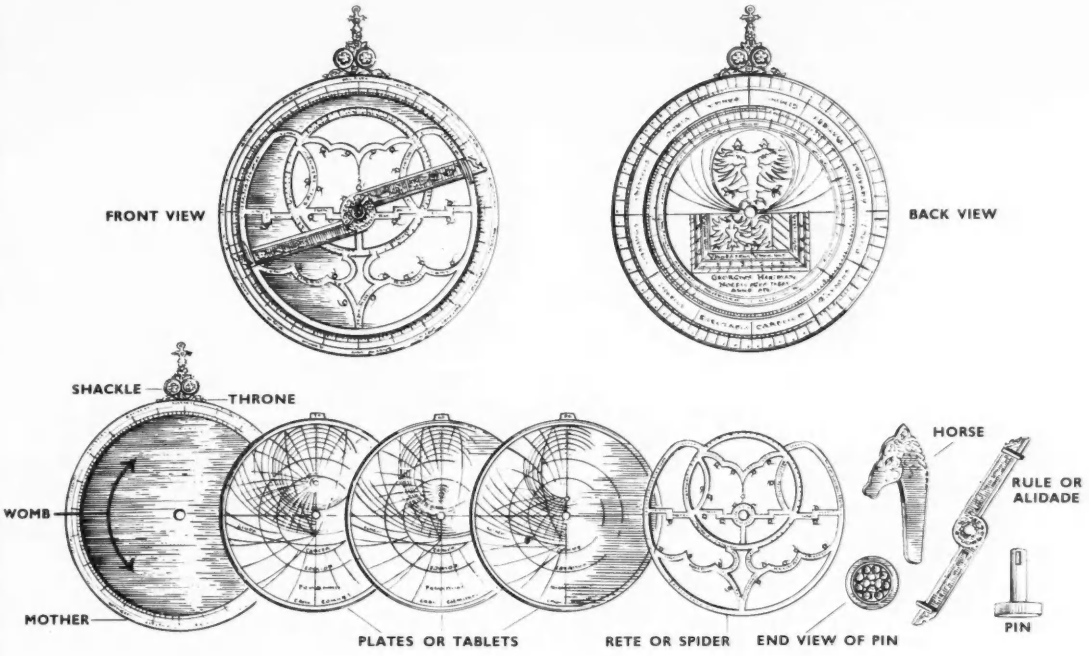
The first English plant at Hayle, Cornwall, came into production in 1940, and was built under licence from the Dow Company and managed by the Alkali Division of I.C.I. in association with the predecessors of The Associated Ethyl Company. The Associated Ethyl Company took over its operation from I.C.I. at the beginning of 1948.

The second plant at Amlwch, which came into production in 1953, with an initial capacity to treat 350,000 *tons* of sea-water per day, not *gallons* as given by Dr. Cook.

An authoritative account of the extraction of bromine from sea water is given in Volume 2 of the *Encyclopedia of Chemical Technology*, and a good description of the Amlwch plant in *The Industrial Chemist* for July 1954.

R. O. GIBSON.

The Associated Ethyl Co. Ltd.,
Ellesmere Port, Cheshire.



ASTROLABE
(16th Century)

This astrolabe, which is 6½ in. in diameter, is inscribed "Georgius Hartman Norenbergae faciebat anno MDXLVIII." There are three tablets for latitudes 42°, 39°; 45°, 48°; and 51°, 54°. The altitude circles are shown for every 3°, and the azimuth circles for every 10°; these latter circles are numbered both ways from the meridian towards the east and west points of the horizon. The rete indicates the positions of 27 stars. The astrolabe is here drawn in such a way that its individual parts can be clearly seen. Only the "horse" is slightly enlarged to show its delicate features. (*Drawn from the original at the Science Museum, London, by kind permission of the Director.*)

THE PREHISTORY OF THE CLOCK

DEREK J. PRICE, Ph.D.

Dr. Price is a double Ph.D., in physics (London) and in history (Cambridge). He has been a Commonwealth Fellow at Princeton, a lecturer in Singapore, and an I.C.I. Fellow at Cambridge where he is continuing his work on the history of scientific instruments under an award from the Nuffield Foundation. He is an acknowledged authority on this subject, having made several notable discoveries, and is consultant to a number of museums.

THE PROBLEM

The origin of clockwork is a key topic in the history of science. Not only is the clock itself important, but the technology of precision gearing is a basic factor in the development of machines. Until a century or so ago clocks were the only really complex machines, so to trace the origin of modern machinery one must always go back to the history of horology. This has been worked out in detail for the period from about A.D. 1500 onwards, and one can follow quite easily the chief evolutionary stages up to the present day. They have proceeded more or less steadily in keeping with general scientific and technical progress.

Until very recently little was known of clocks before 1500. All standard histories of the subject had to conceal the meagreness of information by taking "time-keeping" as their subject. When mechanical details became rare in the earliest period they turned instead to sundials, water-clocks and similar devices, and used these to give the topic an apparent continuity and a pedigree of respectable antiquity. This cannot conceal the fact that we know nothing of the invention of the mechanical clock and its escapement mechanism. The first clocks of the late 14th and early 15th centuries are no less complex and show the same general features as those of much later date. It seems as if the clock was not born, but sprang fully grown into existence at some time between A.D. 1250 and 1350.

Research over the last two decades has made the matter worse. We now know that the first mechanical clocks were no simple timekeepers showing or striking the hours alone. They were highly intricate monumental devices, often erected in cathedrals, and exhibiting numerous astronomical dials showing the motion of the stars and planets and the fixed and movable feasts of the calendar. If a comparable evolution had happened 200 instead of 600 years ago, the turbo-jet plane might have been made before the first steam engine. Things do not ordinarily happen like this, and if they seem to in the case of the clock it indicates some grave fault in previous inquiries.

Part of the trouble has been the preoccupation with the story of "time-keeping". It is now evident that the first clocks showed the time of day only as a secondary function; their main purpose was to exhibit astronomy in a popular and impressive way, thereby showing the glory of God in the heavens.

The rest of the trouble has been caused by a misconception in the history of gear-wheels. As is well known, these were known to the Greeks, and their origin probably goes back to the second millennium B.C. There is, however, a world of difference between the use of a single pair of gears to transmit power or turn it through an angle (as in the water-mill and windmill) and the use of trains of precision gearing to give movements at various speeds for some scientific purpose. Greek and Islamic scientists were interested in many things where gear wheels would have been very useful—for example in their automata and mechanical toys. But all these are worked by strings and pulleys, levers and trip wires, water power and air pressure. Only rarely did they use gears, and when they did—as in the primitive taximeter for recording distance travelled by a carriage—the gears were arranged in the simplest possible fashion. In the general history of ancient and medieval gearing there is nothing that will serve as the ancestor of the first great clocks.

THE TENTATIVE SOLUTION

A clue to the riddle came (as it often does) from a quite unrelated piece of research. Stimulated by the discovery of an astronomical manuscript written by the poet, Geoffrey Chaucer, I was led to examine the history of an almost forgotten medieval instrument for calculating geometrically the positions of the planets. They would now be called "analogue computors", and before the days of the Nautical Almanac they were very useful for avoiding the arduous trigonometric calculations involved. The planetary computor, with its better known companion instrument for star positions, the astrolabe, were to the medieval astronomer what the slide rule is to the modern engineer.

These devices were probably first made by the Greeks, but they soared into popularity when their science reached Islam, and many improvements seem to have been made by Arab astronomers from the 10th century onwards. During the 13th century these computors became known in Paris, Oxford and other centres of astronomy, and a great number of them were made. The basis of the instrument had been to use a series of movable plates inscribed with lines and circles as a mobile geometrical diagram which could be set in

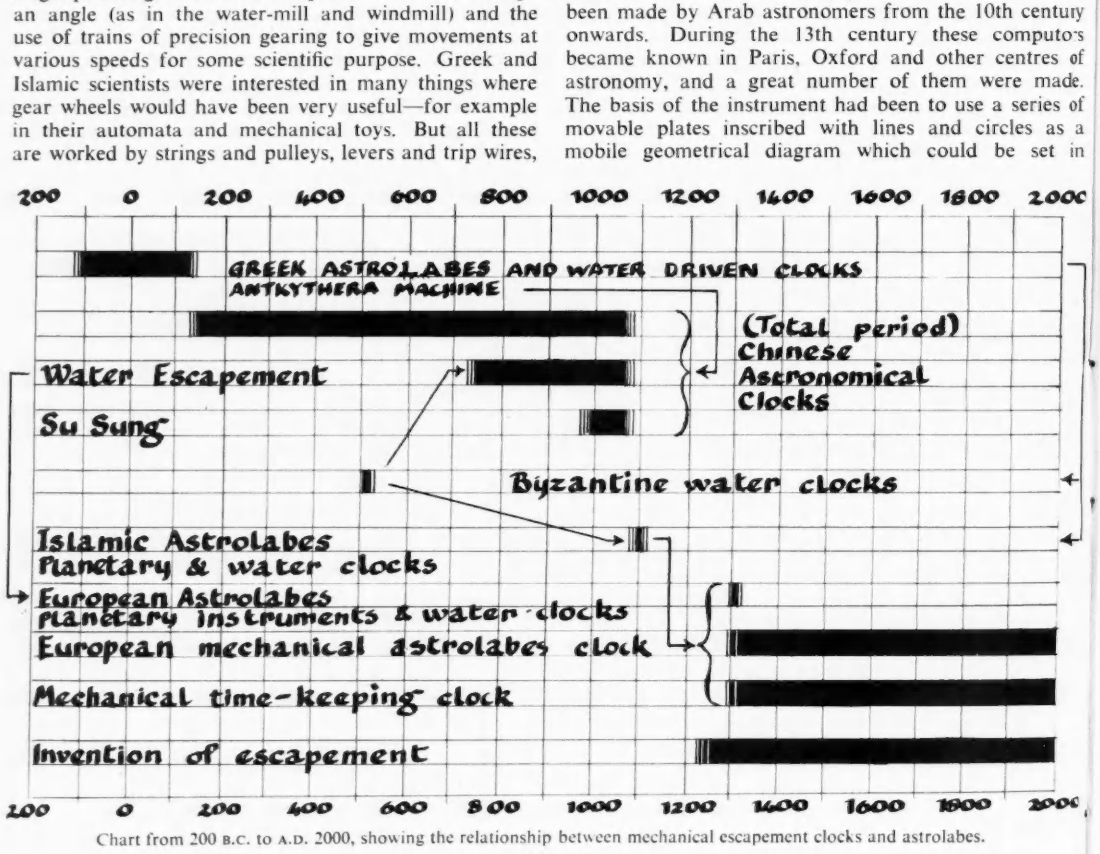


Chart from 200 B.C. to A.D. 2000, showing the relationship between mechanical escapement clocks and astrolabes.

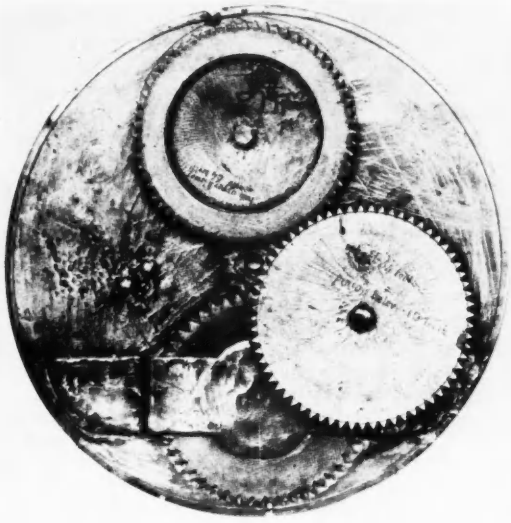


FIG. 1. Internal gearwork from sun and moon movement of an astrolabe made in A.D. 1221, now in Museum of History of Science, Oxford.

position manually for each calculation. One of the first great Islamic astronomers, al-Battani (*c.* A.D. 1000), introduced the fundamental innovation of gearing into a simple calculator of this sort. The gears were so arranged that when a scale representing the place of the sun was set into position, another for the moon automatically fell at the correct angle. This is the first time that gearing had been used in such a way, and it is interesting that the device also includes a window showing the phase of the moon. It is almost identical in design with the lunar phase indicator still used in many clocks.

By a miracle of preservation one of these instruments designed by al-Battani still exists. It was made in A.D. 1221 by a Persian craftsman, and may now be seen at the Museum of the History of Science, Oxford (Fig. 1). Another of these geared planetary devices is in the Science Museum, London. It was made in France, *c.* 1300, and although incomplete it is important as the earliest known example of European manufacture (Fig. 2). It is remarkable that the only known pieces of clockwork before the clock are both planetary computors, and both constructed as an addition to an astrolabe. They are, of course, manually operated and the "clockwork" contains no sort of weight drive or escapement.

We know, however, that the astrolabe, though never geared, was often mechanised. Classical writers describe special forms of astrolabe in which the disc carrying the star map is made to rotate slowly so as to simulate the diurnal motion of the heavens. The source of power was apparently the sinking float of a water-clock which was connected by a string and pulley fixed on the axle of the disc. Two fragments of such discs have been found in archaeological excavations, so one can be

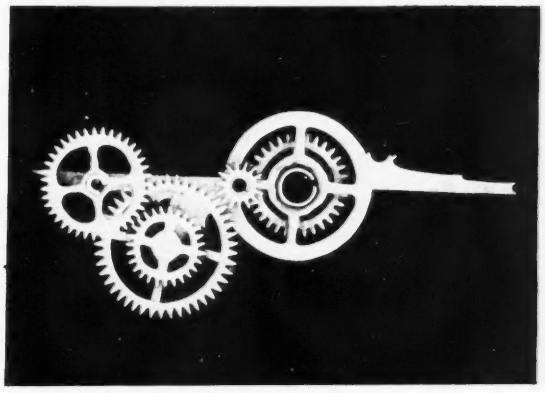


FIG. 2. This instrument, which is of French manufacture, is 6 in. in diameter. The rete indicates the positions of 22 stars, and bears the usual circle representing the ecliptic with the degrees on the signs of the zodiac. It is outstanding for its train of toothed wheels worked by means of the toothed periphery of the rete, and used apparently for the purpose of indicating the age of the moon.

The rete, which is constructed for the southern hemisphere, is in an unfinished condition. One side of the tablet is engraved "Engeltierre" and the other side "Hollande". (*Crown copyright from the exhibit at the Science Museum, London.*)

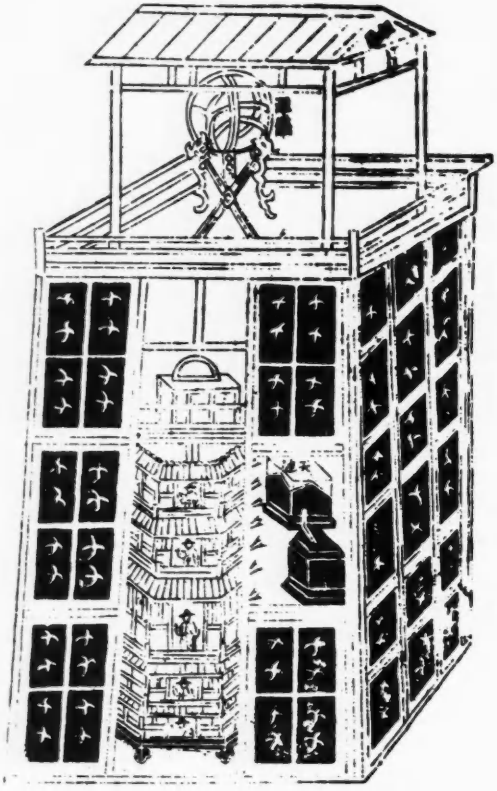


FIG. 3. Original illustration of the astronomical clock-tower built by Su Sung, A.D. 1088.

quite certain that these devices were made as early as the 2nd century A.D. Again there is a link with the history of the clock, because the rotating star map explains why the earliest mechanical clocks had a turning dial and a fixed pointer—an arrangement since reversed.

It is clear then that by 1300 there was a considerable activity in the making of planetary calculators, and in some of these, gear-wheels were being used for the first time in a scientific context. There was also a tradition of other astronomical models containing star maps turned by water-power. It must not be forgotten that the powerful mathematical structure of astronomy was as impressive and complicated to the Middle Ages as Einstein is to us. Nothing could be more natural than to combine the two old traditions and make a powered and geared machine—a sort of planetarium or orrery—which demonstrated this pinnacle of Man's understanding and the glory of the Divine Will in the ordained machinery of celestial motions. (See Fig. 4.)

Thus the first great astronomical clocks came into existence. At first it mattered little whether they kept good time; it was sufficient that they went through the right motions. Later, one can believe, some sort of regulator was found useful, and the escapement made its appearance, perhaps as a modified form of oscillating jackwork or striking action. Still later, towards the end of the 14th century, social change led to an emphasised importance of correct timekeeping in the cities and in religious communities. At this point the essential elements were abstracted from the astronomical machine; the gearing, the escapement, and a single dial and striking movement were set up separately. The first ordinary clock had been born as a fallen angel from the world of astronomy.

THE RESEARCH FRONT—EAST

It is usually thought that the mechanical clock was unknown in China until it was brought there by Jesuit missionaries from the West. Having, however, heard of astronomical models which are said to have been built in China in medieval times, I consulted the authority on the history of Chinese science, Dr. Joseph Needham. Together with his assistant, Dr. Wang Ling, we have now completed a translation and study of the available texts. Although readily available as printed books they had not previously been translated or studied because of their technical complexity.

We now have the complete plans of a great water-powered "clock-tower" built by an imperial tutor, Su Sung, in A.D. 1088. It was more than 30 feet high and full of machinery; on the roof was an armillary sphere weighing about 20 tons, and in a chamber within was a

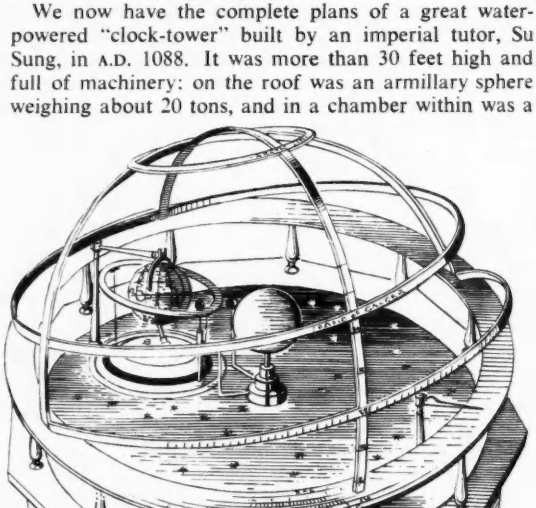


FIG. 4. Troughton's Small Orrery. A miniature orrery measuring only one foot across. It illustrates the motions of Mercury, Venus, earth and moon. It is engraved "Troughton, London" and was made in the second half of the eighteenth century by a forerunner of the present firm of Cooke, Troughton and Simms, Ltd., York.

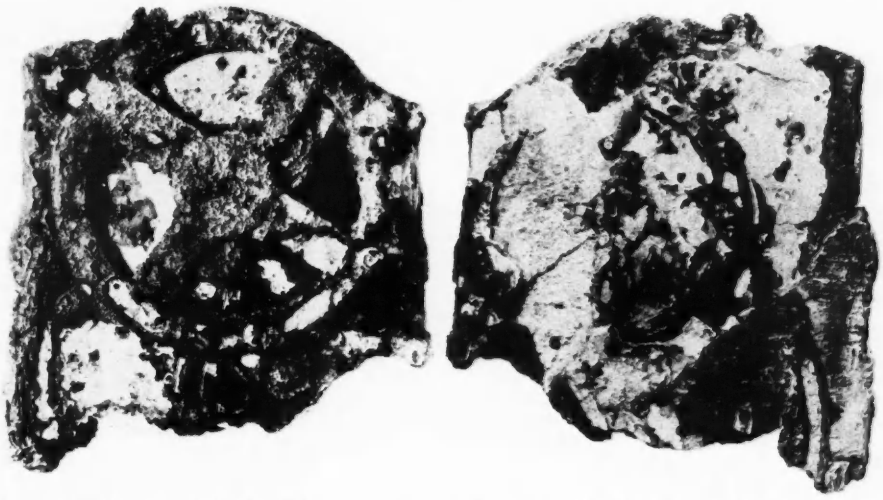


FIG. 5. Front and back of the largest of the fragments of the Antikythera machine. (*By courtesy of the National Museum, Athens.*)

great celestial globe 4½ feet in diameter (Fig. 3). The globe and sphere were driven round in time with the heavens, and every quarter-hour a series of jacks and automata rang bells and gongs and indicated the time of day and night. Similar, though perhaps less complicated, clocks had been built before in China in A.D. 725 and 979, and there are indications that the tradition may have started as early as the 2nd century A.D. It thus runs exactly parallel with the European development of astronomical calculators and models just described.

What is most remarkable in the Chinese devices is that they contain a mechanical means of regulating the water-wheel which provides the power. Each bucket of the wheel is held by a weighbridge and trip-lever mechanism so that it can only be set off when the bucket has received a quarter of an hour's supply of water. Such an action is intermediate in principle between the ancient water-clock and the mechanical escapement. It is almost a missing link in the chain of evolution, and now that we know of its existence it seems likely that a similar principle may have been used in some 13th-century European water-clocks, hitherto unexplained. Whether the idea of the escapement came from China at the time of Marco Polo yet remains to be seen.

THE RESEARCH FRONT—WEST

In 1901 an ancient sunken treasure ship was discovered off the island of Antikythera between Greece and Crete. Divers brought up a superb collection of statuary which is now in the National Museum at Athens. They also recovered the remains of a curious piece of machinery, once enclosed in a wooden casing. Two thousand years under the sea had reduced the object to a mess of corroded brass plate and powdered verdigris, but fragmentary inscriptions can still be read, and there are the indisputable remains of a large number of assorted gear-wheels arranged in several trains. These are connected with a series of discs and bands, some of them being divided and marked in degrees and signs of the zodiac. The inscription makes it evident that the machine is somehow intended to work with the positions of the sun, the stars and the planets. The largest fragment (Fig. 5) shows, in spite of the corrosion, that this machine was as involved and as finely built as any 16th- or 17th-century clock.

The archaeologists insist that the Antikythera treasure cannot be later than the 2nd century A.D., and the epigraphers agree that the form and style of the inscription on the machine point to a similar date. If it is genuine, the Antikythera machine must entail a complete re-estimation of ancient Greek technology. We know remarkably little about later Greek technology because it is only the great literature and philosophy and the more popular scientific texts which have survived. However, the Antikythera machine is so far superior to anything else known that it can hardly be believed. Its discovery 55 years ago received little publicity, but, in its way it was as spectacular as if the opening of Tutankhamen's tomb had revealed the decayed but recognisable parts of an internal combustion engine.

If one accepts its evidence, however remarkable, the Antikythera machine must be the most ancient example of an astronomical device. Oddly enough there is a persistent literary tradition that Archimedes, amongst others, made a working model showing the stars and planets. One wonders if it is just possible that the fragments we have are the venerable remains of such a device. Certainly it is essential that they be most minutely examined so as to discover details of the gear-work and the underlying astronomical theory. If this can be done, in spite of the tremendous technical difficulties and administrative complications associated with political tension, it may be possible to understand its evidence. It may well be the most valuable relic of Greek science and the oldest piece of clockwork in the world.

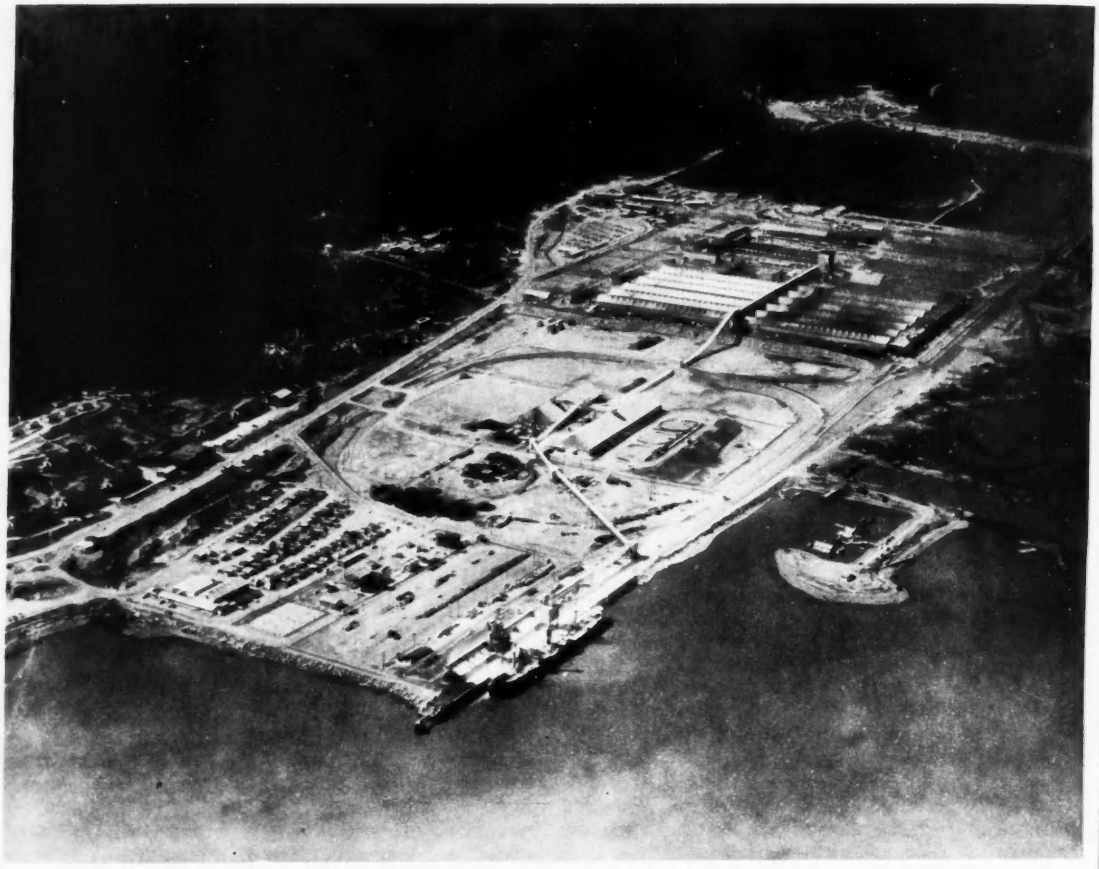


FIG. 1. Kitimat, aerial view looking north-west showing smelter area. Note unloading of alumina at permanent dock and the graving dock.

THE KITIMAT STORY

BY A STAFF WRITER

One hundred and fifty-six years ago, at the opening of the 19th century, aluminium was unknown. In the 1850's a table-service that Napoleon III had made of aluminium cost more than the price of an identical one in gold. Yet today the only metal of which there is an annual consumption larger than steel is aluminium. Its price naturally reflects its changed status.

The key to this spectacular expansion was the discovery of a means of cheap production. The ore from which the metal is obtained is not rare—indeed it represents one-eighth of the globe's crust—but releasing the metal from the raw material (bauxite) proved technicologically so subtle that this fact alone preserved until 1886 the price of aluminium at the level of the precious metals. The result of Hall and Héroult's success in reducing aluminium oxide by a novel electrolytic process promptly cut the price by a quarter. Nevertheless to exploit this discovery fully, and to produce aluminium in huge quantities at the lowest possible cost—required the bringing into conjunction of features not readily found together in nature, namely, the sources of bauxite (all within the Tropics), massive electric power, and first-class transport facilities.

Unhappily, the impulse and grand-scale planning of war was necessary to fuse these elements into the reality of actual development projects. The last war used up all the aluminium that could be put on the market. The years of cold war since, combined with a period of intensive reconstruction and industrial expansion has maintained the demand well ahead of supply. But these conditions have quickened engineering imagination, brought into focus parts of the world that have never

been thought of together before—and provided the colossal capital sums needed to put through development schemes of the grandest sweep.

Britain is currently using 252,000 short tons of aluminium per year on new aircraft, new buildings, new electrical installations, and on other work. To supply Britain and other countries of the free world, the wilderness of a forbidding corner of north-western Canada has been tamed and harnessed in forty months. A city of 50,000 has risen where six years ago only a few Indians wandered in summer months, and to Canadian shores come ships with oxide, the mining and processing of which in Jamaica brings new employment to West Indians half the world away.

The production of 1 lb. of aluminium ingot requires 10 kWh of electricity. The electrical power consumed in producing a ton of aluminium, it has been estimated, would meet the demands of a normal household for ten years. Until atomic power is an economic reality the siting of aluminium smelters must therefore depend primarily on a nearby source of massive hydro-electric power.

Such untapped reserves of electricity are nowadays rare. Within the Commonwealth they are to be found in the few large areas remaining undeveloped, such as the province of British Columbia in Canada, and in British Africa. Surveys had been made of the Tahtsa Lake area of British Columbia, once, twice, three times, between 1874 and 1950. The acute world demand for aluminium made the possibilities which these surveys revealed economically workable.

In 1948 the Aluminum Company of Canada started negotiations with the provincial authorities of British Columbia, and funds were raised for the initial capital outlay of a scheme which is expected, ultimately, to cost in excess of £200 million. The biggest development job ever undertaken by private enterprise* was "on". Kitimat found itself on the map.

THE PLAN

"Kitimat" is shorthand for the whole development project. This comprises five distinct engineering schemes and is flung across an area more than 200 miles long. The name actually derives from the site chosen for the smelter at the head of the Douglas Channel, a navigable inlet running 80 miles up from the northern Pacific.

The unusual topography of this coast range of mountains has provided the opportunity which the planners of Alcan† have so boldly seized. The crest of

* During the war the British Government made a £40 million loan to the Aluminum Company of Canada Ltd. for development. The substance of this loan was absorbed before the Kitimat project was started, however. The Company did not receive money from any other public source.
† Alcan is the term by which the Aluminum Company of Canada is best known.

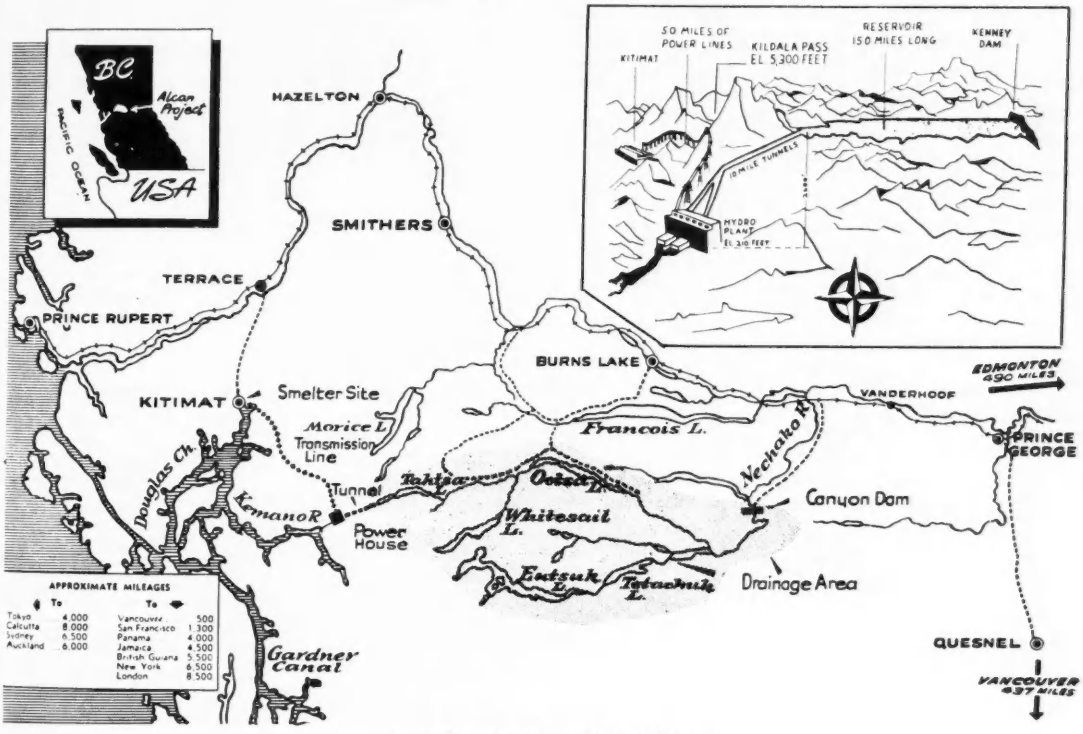


FIG. 2. Map showing position of Kitimat.

FIG. 3. Nechako, aerial view of dam area.

the range is only a few miles from the sea. Moreover, due to heavy glacial action during the Ice Age (when the whole of British Columbia, save the highest mountain peaks, was iced over), long, deep, narrow valleys were scoured out on both sides of the crest. The sea flowed into the westerly valleys to form long fjords; the fjordheads (at sea level), lying within a mile or two of the high peaks of the mountain barrier. The valleys on the eastward side descend more gently, but the heads of the lakes approach equally close to the crest of the mountain range. The westerly point of Tahtsa Lake, at the end of a 150-mile lake-chain, is only some 15 miles from sea-level (Kemano) on the other side of the mountains.

The engineers' plan had a magnificent simplicity. The outflow of the system of lakes would be stopped at the eastern end. Then, when the narrow boat-shaped vessel of water thus formed was full enough it would be forced back over its opposite "lip", *through* the mountains to the seaward side. Here, the fall of water would be turned into power. Then the electric power in turn is to be transmitted to Kitimat itself, some miles away at the head of a navigable channel where the Jamaican oxide may arrive in ships. The power would be used to make aluminium at Kitimat and this would then leave for the markets of the world by water through the same sea-channel. Eight hundred and seventy-three billion cubic feet of water would thus be turned into 550,000 tons of aluminium each year.

The successful execution of four unconventional construction jobs was fundamental to the whole plan. The dam necessary to hold back a 150-mile stretch of water from its accustomed canyon outlet would be the largest rock-fill dam in the world. A tunnel running 10 miles through the solid rock of the mountain barrier would bring water in two 2600-foot-head, 11-foot-diameter pressure-conduits (the largest pressure-conduits known) to turbines on the other side. At the foot of the mountain a power-house containing ultimately sixteen of the world's most powerful generators had likewise to be excavated and installed inside the mountain. And, finally, to bring the power to the aluminium smelter, a

power-line carrying the largest conductors ever made must be flung over 50 miles of ferocious snow-clad mountains. At one point the chain of pylons rises 2000 feet above the tree-line to a 5300-foot pass, where 80-mile-an-hour gales range in winter and the snow lies 20 feet thick.

The smelter alone in the project was of conventional design. It was simply to be the largest ever built.

Of course these five main construction features of the total development were not begun in sequence. But it is convenient to treat them here consecutively, beginning at the stage farthest from the aluminium, at the Nechako Canyon through which the lakes had previously been drained to join the Fraser River. In fact the work on the eastward dam (now to be called Kenney Dam) and the clearing of the foreshore at Kitimat in preparation for the smelter, the building of port facilities and a city, began during the summer of 1951 almost simultaneously.

THE DAM AND STORAGE RESERVOIR

Rainfall over the watersheds draining into the long lake-chain above Nechako Canyon varies from 100 inches a year at the western end to about 20 inches at the lower eastern end. The watershed area above Kenney Dam is practically 5500 square miles. A further 290-square-mile watershed, that of the Nanika-Kidprice lakes, can eventually be diverted into the main system. When the storage reservoir has risen to its scheduled level it will have a capacity of 873×10^9 cubic feet, although the rise in level will only be 15 feet in the Tahtsa Lake, at the western end. The reservoir surface area will then be 358 square miles, double that of the original lakes; even so the depth of water at the upstream face of the dam will be little more than 300 feet. The full reservoir surface-level will stand at 2800 feet above sea-level—with the inlet to the power tunnel nearly 100 feet below this surface.

The Nechako Canyon site of the main dam, was too deep and narrow for the usual coffer-dam procedure for drying out the channel where the dam was to go. A new river channel was therefore drilled into the bank upstream, carried 1539 feet inside the mountain in a sweeping arc, and the water debouched again into the river well below the dam site. This diversion tunnel was cut and completed in two months during the summer of 1951.

The thousand men working on this section of the development were now able to start clearing the river bed. Canyon walls and water-channel were stripped down to the solid bed-rock. A concrete slab, 150 by 82 feet and 10 feet thick, was spread on the cleared reservoir floor. Upon this, the placement of the rock of which the dam was to be formed, began to rise on May 20, 1952.

The rock came from quarries in the surrounding mountains. Four million cubic yards of filling rock was used. It took the thousand-man labour force six months to shift and place this material. At 45-second intervals throughout those summer months one of a fleet of trucks dumped its load on the dam, its drivers' movements radio-controlled from a central tower.

The construction of the rock-fill dam is of special interest in the case of the Kenney Dam since it holds a highly critical position at the head of a major tributary of the Fraser River. Here is the technical description of the Chief Engineer of the Power Department of Aluminum Laboratories Ltd.,* Mr. F. L. Lawton, who has been closely associated with Kitimat:

> ". . . the load-carrying element is a heavy rock-fill, thoroughly sluiced, supporting on the upstream slope an impervious section of rolled-earth construction enclosed between suitable filter layers. The upper section is loaded with quarry-run rock to retain the filter layers and impervious core, and resist wave erosion. The impervious core extends from a cut-off trench in sound rock to near the top of the dam.
>
> The function of the downstream filter layers is to prevent the impervious core material from being forced into the rock-fill by the water pressure, whereas the upstream filter layers perform a similar function with respect to the upstream blanket of quarry-run rock. The downstream filters comprise three layers; immediately downstream from the impervious core a layer of sand ¾ inch and smaller; next crushed rock or gravel, 3 inches; and, finally, adjoining the main rock-fill a layer of 10-inch selected rock. The upstream filter is similar but in the reverse sense.
>
> Below the impervious core, effective cut-off is assured by a grout curtain. This was developed by grouting the upper 25 feet of rock at pressures of about 20 lb. per square inch, then continuing to the necessary depth by deep holes drilled through the consolidated upper zone, using higher pressures."

Another point worth noting is that the original 1-in-1·5 slope of the upstream face was increased to 1-in-2·5 during the model tests at the University of California, as an additional safety measure. In view of the dam's elaborate and scientific packing, the claim that its life will be measured "in geological, not historical time" is probably justified.

On October 8, 1952, the diversion tunnel above the dam was closed and the storage reservoir began filling. The water has been rising ever since. The 2800-foot-elevation level should be reached in 1957.

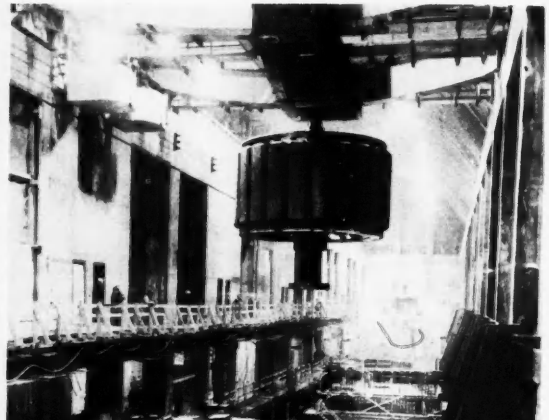
Colouring an account of the construction of this, the world's largest rock-fill dam nearly 3000 feet up in the mountains, there should be a sense of the acute inaccessibility of the region and the human hardships that this must bring. Nechako Canyon is nearly 100 miles from the nearest railway station. To bring the heavy equipment and the men to the site a heavy motor-road had to be driven 60 miles through virgin country. The Canadians did this in twelve weeks flat.

THE POWER-TUNNEL

The storage capacity of the reservoir permits a regulated flow estimated at 6920 cubic feet per second for the power-house turbines. But first, the water had to be thrust 10 miles through solid rock to reach those turbines.

The boring of the tunnel started on October 22, 1951, from the western shores of Tahtsa Lake. On November 4 the bore into the mountain from the seaward side

* Aluminum Laboratories Ltd. is a subsidiary of Aluminum Ltd. in the same group of companies as Alcan.



FIGS. 4 and 5. Kemano. General view of power-house. *Left*, Vast underground excavation during work inside Mount DuBose prior to the installation of equipment. *Right*, the power-house receiving a Canadian Westinghouse generator rotor.

began. Two further mining crews attacked from a midway shaft driven into Mount DuBose at Horetzky Creek; one of these crews bored eastward from this point, the other westward.

Mining operations on the western mountain face were complicated by the need to start drilling half a mile up a heavily wooded and almost cliff-steep slope. An overhead cable-railway solved this problem. The cable-car, weighing 9 tons itself, could convey 20 tons of machinery or sixty men per trip.

Within the tunnel highly co-ordinated team-work operating a newly developed large-scale drilling technique chewed through the rock at the rate of 15-feet-plus in two hours. A tunnelling team consisted of forty men. Ten worked on each face of the tunnel, perched on four platforms on a movable scaffold known as a "jumbo". Up to 100 blast-holes 15 feet deep were drilled. Then the jumbo was pulled back and the drill-holes plugged with explosive. After the detonation the broken rock was loaded into trolleys, dragged to the entrance and dumped. Then the cycle would be repeated. The tunnelling continued round the clock, the men working shifts, for twenty months. On December 2, 1953, two grimy miners grinned at each other through a jagged hole deep inside the mountain. The tunnel from the east had met the tunnel from the west —dead on centre! Three times the world tunnelling time had been cut; the final record was in 1953 when 282 feet were bored in a single 6-day week. (This was through granodiorite, a most satisfactory material for drilling.)

The completed tunnel was 10·1 miles long with a diameter of 25 feet. A second, following the same route, but 300 feet away, is envisaged in the final development.

THE POWER-HOUSE

Kemano hydro-electric power-plant is to be the largest underground power-house in the world. When the full complement of sixteen 150,000 horse-power generators are installed it will have a total capacity over three times the ultimate installed capacity of Harspranget in Sweden, the closest rival. Work on digging out the power-house cavern began at the end of the summer of 1951, and this job alone took nearly two years. The plant is nearly a third of a mile inside the mountain, so a 27-foot-wide access tunnel had first to be driven as far as the location of the power-chamber. A total of 570,000 tons of rock made room for this. The cavern necessary to house the full eight generators envisaged at the completion of Stage I (the "6-year plan" for the scheme) is ample to hold the *Queen Elizabeth*. Today the power-house is 82 feet wide and 135 high, and is 700 feet long. To install the eight more generators allowed for in the plans the building must be cut another 400 feet into the rock. It will then be more than a quarter of a mile long.

The Kemano generators are driven by the largest multi-nozzle impulse-turbines ever devised. These turbines are vertical, single-runner, 4-nozzle type designed to produce 150,000 h.p. at 327 revolutions per minute. They drive directly 3-phase, 60-cycle, 13,800-volt

generators rated at 122,000 kVA. The power from each group of generators feeds into a bank of three single-phase 89,000 kVA transformers. A 300,000-volt, 4-inch-diameter power-cable, with 60 lb. per square inch oil-pressure, carries the transformer output 2000 feet to the surface switchyard. (This power-cable is runner-up for the world record; the only larger one is the 380,000-volt cable in use at Harspranget.)

To carry out all this work a settlement of about 5000 people was established at the foot of Mount DuBose by 1953. Apart from the forbidding country round, they were snug. They had their own neat homes, schools, churches, and in the cinemas first-run Hollywood films were screened. A two-lane road ran 10 miles down the valley to the anchorage on Gardner Canal—and the rest of the world.

THE POWER-LINE

It is certain that without helicopters the power so boldly seized at Kenney Dam and Kemano would never have been piped across the mountains to the aluminium ore at Kitimat. Grit can get men so far but it cannot swing heavy loads to an eagle's eyrie—and this was the sort of task that was now ahead. Between Kemano and Kitimat lies 50 miles of savage mountain country, clogged with snow and lashed by winds that could rise to an 80-mile-an-hour gale off the sea. At one point on the route the transmission line must go over a 5300-foot pass, the highest elevation in the whole project. In these conditions hundreds of specially strengthened pylons had to be set up and the massive transmission cables rigged—the biggest ever made and designed to support a 5-inch sheath of ice if necessary. It was difficult enough getting the men to some of the sites, not to speak of heavy equipment.

Seven helicopters were brought to Kitimat, the largest fleet to be used for civilian purposes at that time. But there were other snags. Carl Agar, one of Canada's best pilots, was called west to pioneer high-altitude landings and take-offs. The rarefied atmosphere and treacherous mountain down-draughts were variables that no one had experienced on this scale.

But the venture worked. In fact the helicopters became so indispensable that on favourable days they flew seventy-five round trips on a tight schedule—more than at the height of the Berlin airlift, as somebody pointed out! Each machine would work on a four-hour shift, back and forth, back and forth, without ever touching down.

Meantime on the mudflats below at Kitimat the new aluminium smelter had been going up and 4 miles away the new town was rising, a planned community scheme to house the rapidly increasing population in the wilderness. Port facilities were also installed on the cleared foreshore. Stalwart as these rapid achievements were they seem dwarfed by the rest of the development story.

On July 15, 1954, the last switch was made. The power from the lakes in the mountains began to heat the smelters. The plant was officially opened by the Duke of Edinburgh a fortnight later and the first ingot poured in his view.

FIGS. 6 and 7. *Top*, helicopter being used at Kemano for the air-lift to Horetzky. *Bottom*, Stringing of world's largest aluminium cable proceeding along mountain section of 48-mile transmission line from Kemano to Kitimat.

In 1874 when the first survey of this area was made by Charles Horetzky, surveyor of the railways, he wrote of these mountains—"A terrible silence, broken only now and again by the dreadful crash of some falling avalanche, reigned over this scene of desolation." When he led a party of three white men and four Indians through a gap in the mountains and saw beneath, the water of Tahtsa Lake like a jewel in the waste, he was immediately struck by its "brilliant light blue colour"—the first excitement for the eye for many weeks.

Now, eighty years later, "the terrible silence" is pierced by the high-pitched hum of the turbo-generators and the "scene of desolation" is peopled by a thriving community of many thousands. Last year (the first complete year of smelting at Kitimat) over 90,000 tons of aluminium were produced. By the end of 1956, when six generators will be in operation, the output will have increased to more than 180,000 tons. And, if world demand continues to increase at its present rate, sixteen generators producing power for 550,000 tons of aluminium a year may soon be in operation.

(It might interest readers to know that two films on Kitimat are available. They are 16 mm. colour-sound films and may be obtained on loan from Mr. R. F. Tayler, Northern Aluminium Co. Ltd., Banbury Oxfordshire.)

THE BOOKSHELF

Control of Nuclear Reactors and Power Plants

By M. A. Schultz (*London and New York, McGraw-Hill, 1955, 313 pp., 56s. 6d.*)

The unique problems imposed upon control designers by the nature of the chain reaction are further complicated when plant for the conversion of the nuclear power into useful power is connected to the reactor. In this book the author has approached the design of control systems for nuclear reactors by the formalism of servo-mechanical theory.

The argument is developed logically and clearly, liberal use being made of the mathematical disciplines in common usage among servo-mechanism engineers. After a short introduction, the minimum of nuclear physics, to give an understanding of the main factors which affect the reactivity of the reactor during operation, is presented. Reactor Kinetic equations for a simple reactor and for various types of reactivity input of increasing complexity are developed, and solved. This leads to the development and solution of equations relating to automatic control problems for the simple reactor operating in the power range.

Having completed the theoretical approach thus far, the author devotes some space to a general discussion and description of practical methods of control rod actuation.

The effects on the control of the reactor, of successively connecting a closed coolant circuit, boiler or heat exchanger, and turbine to it are considered next, together with the effects of various types of steam plant programme. In all cases the stability of the control system is investigated. Automatic control is postulated since automatic systems can always be made to fail to safety whilst with purely manual control, the fallibility of the human operators must always be considered.

Radiation detectors for the provision of the required control signals are then discussed, descriptions of various types of neutron counter being given along with a discussion of their calibration.

The problems of operational control are discussed, emphasis being placed on the problems of start-up. The start-up period is considered to be the most difficult of all in reactor operation. Shut-down philosophies and emergency shut-downs only are considered.

Finally a section is devoted to a discussion of analogue computing techniques and the design of simulators in order to determine the effect on the stability of the system of the variation of reactor and plant parameters, in the laboratory, without recourse to expensive experiments on the plant.

The text is copiously illustrated by diagrams and graphs derived from numerical solutions of the various equations derived. Sets of examples covering the work of each chapter are a useful addition whilst the comprehensive bibliography appended to each chapter should ease the task of readers wishing for more detailed accounts.

Some inaccuracies appear to be inherent in first editions, so this point need not be laboured.

There would appear to be a subtle change in the safety philosophy of the author as the book progresses. The traditional, super-safe philosophy postulated at the beginning gradually appears to change into the "aircraft safety" philosophy in which each item of plant must be able to protect itself.

This is essentially a book for the design engineer and is well worth studying by the many people who are now entering the nuclear power station field. It will be a most useful introduction to the subject, but the reader should regard the contents as stimulating and provocative rather than as authoritative and final. H. G. DAVEY

The Pocket Guide to Wild Flowers

By David McClintock and R. S. R. Fitter (*London, Collins, 1956, 340 pp., 25s.*)

A good deal of expert knowledge is required before one can use a standard flora, such as Clapham, Tutin and Warburg's *Flora of the British Isles*, and succeed in obtaining an accurate and reasonably swift identification of a particular specimen of flowering plant. Such works are intended primarily for specialists, and they cannot be recommended to the non-specialist who needs something much simpler. The ideal for his purpose is a book which contains a set of simple but sound bifurcating keys, *plus* a complete set of coloured pictures and a complete set of compact verbal descriptions for all the species. The Swedes, as is fitting for the countrymen of Linnaeus, are particularly well served in this respect and they have several such books at their disposal. A typical one is *Svenska Växter*, published by Nordisk Rotogravyr. This is a beautifully arranged book; its keys are excellent (and designed on the best scientific lines), and by using them one arrives at the right page which contains the verbal description of the species most likely to be involved. On the same page one finds descriptions of all the related species, and opposite it a plate of accurate coloured illustrations showing every one of those species.

Another type of book which the ordinary person can use with great success is exemplified by the French book *Nouvelle Flore* by Gaston Bonnier and G. de Layens. This is very simple and swift to use since the keys are very well designed and contain line illustrations of most of the key features of plant structure upon which accurate identification depends. Probably the non-specialist is happiest, and gets the best results, when he can use a book like *Svenska Växter*, but there is no doubt that he can obtain good results with a work like *Nouvelle Flore*.

The authors of this Pocket Guide published by Collins do not rely to any great extent on the use of keys. One needs to know which family the plant belongs to before one can start using any of the keys. Many tyros using this book will probably content themselves with the use of the "stamp matching" method, comparing their specimen with the 600 species which are illustrated in colour. There are also 700 line illustrations. The authors have provided compact verbal descriptions of all the species. It is certainly one of the most comprehensive guides on the market, for it not only covers all the native species but also includes such things as the pitcher plant called *Sarracenia purpurea* that has become naturalised in bogs in Northern Central Ireland, and such garden escapes as *Oxalis incarnata*.

On the whole, the colour plates are excellent. The succession of plants figured in these plates is decided according to colour; the purple flowers, the reds, the yellows, all come together, which in some ways is a great convenience to the "stamp matcher" though such an arrangement does have the disadvantage that it separates the members of particular families to a great extent. There is no doubt that a great many people will find the book a useful aid to the identification of the wild plants which they collect. Whether it will give them quicker results than a book on, say, the lines of Bonnier's various floras is another matter. It could be quite an amusing piece of "time-and-motion" study for someone to test which kind of flora gives the speediest answers to identification problems. W. E. DICK

"Weather and the Land". Prepared by the Agricultural branch of the Meteorological Office.

(*London, H.M.S.O., 1955, 3s.*)

Mr. L. P. Smith and his colleagues in the Agricultural Branch of the Meteorological Office are to be congratulated on this publication which is helpful and useful to the man on the land. Chapters three and four will be found particularly useful and will repay very careful reading. These two chapters deal with the details of weather and climate which so closely affect all growers and the interpretation of weather forecasts. Students who are interested in the elements of the relations between the weather, the climate and growing practice will find a lot that is of interest, while growers who have weather problems may well find here an approach

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to an answer which may be obtained in detail from sources listed in Chapter five. The tables and maps will, some of them, be new and useful to growers, e.g. the maps showing: average dates when the growing season starts; the frequency of irrigation need; the average date of the last screen frost. This pamphlet clears the way for a book on agricultural and horticultural meteorology, which will inevitably follow when sufficient information is available.

Minor criticism of the booklet might be made in one or two directions. The subject-matter is so varied that an index, at any rate to the agricultural and horticultural aspects concerned, would have been very useful. If space was required for this it would easily have been possible to omit a large proportion of the synoptic charts shown. The fact that there is hardly any reference made at all to the chief crop of this country, and the crop for which this climate is ideally suited—namely, grass—is a little surprising. The cloud pictures printed in the centre of the book could have been considerably more useful if the captions had been elaborated, and their agricultural and horticultural significance stressed on the spot instead of in the text. Perhaps the reviewer may also be permitted a quiet word of protest about the cover and title-page. Only close inspection of the background picture on the cover reveals that it depicts a fine day. A casual look suggests that it represents the countryside about to receive a Stygian downpour. The actual type on both cover and title-page represents the usual collection of assorted sizes and founts which one has come to accept from the Stationery Office. Surely there will come a time when the Government can afford to employ just one typographer, if only on a part-time basis! It will then perhaps deliver something more like justice to its authors.

G. L. HOGBEN

The Origin of Vertebrates

By N. J. Berrill, F.R.S.C., F.R.S. (*London, Oxford University Press, 1955, 248 pp., 25s.*)

This book is the culmination of a prolonged and fruitful study of the Ascidians. To most zoologists the sea-squirts are one of three peculiar and apparently unrelated groups which, by virtue of their possession of a notochord at some stage in their life-history, are entitled to inclusion with the vertebrates in the Phylum Chordata. Over the years Prof. Berrill has come to believe that their importance has been vastly underrated and that they are in fact ancestral to all forms of chordate life with the exception of the Hemichorda.

The Ascidians, Prof. Berrill argues, are primarily a group of sessile, non-chordate filter-feeders. The tadpole larva, however, does possess a notochord and a tail and is therefore to be regarded as chordate. This larva is not inherited from some more typically chordate ancestor but has been evolved to meet specific Ascidian requirements of dispersal and site selection. In the author's view, some such larvae became neotenous; that is they failed to metamorphose into sessile adults and became sexually mature as free-swimming organisms. The present pelagic tunicates are direct descendants of this neotenous form.

At a later date certain of these tadpole-like pelagic forms began to feed on organic detritus descending into the sea from river systems. The necessity of maintaining station against a current favoured increase in size, metamerism (primarily of the tail musculature), the development of certain special sensory organs and a corresponding increase in the complexity of the central nervous system. Continued evolution along these lines resulted in a form with a well-developed head and a powerful body, capable of making progress against a river current and thus of penetrating into inland waters. Ultimately some of these forms, by virtue of a larger egg, were able to breed in the inland waters and forsake the sea completely.

An increase in the velocity of river currents at this time (for which some geological evidence is claimed) effectively isolated the fresh-water forms and drove the remainder back to the sea. Amphioxus is a relic of this remainder, having lost the special neurosensory equipment needed for swimming up rivers and having adopted a semi-sessile habit not in keeping with its anatomy. As Prof. Berrill neatly puts it: Amphioxus has contrived to survive because it lost its head.

The landlocked forms, as they increased in size and complexity, had to cope with problems of osmo-regulation and of calcium and phosphorus metabolism. Prof. Berrill regards the development of dermal bone not as armour against some unknown enemy but as a physiological response to a tendency for calcium and phosphorus to accumulate. In this way there emerged an active, lightly boned Ostracoderm from which most zoologists would be willing to derive all fossil and modern vertebrate forms.

The book is, above all, readable. The argument is so well presented that it exerts over the reader something of the fascination of a first-class detective story. Its clear and well-chosen illustrations and its wealth of example and explanation make it accessible to a wider readership than might be supposed.

R. P. HILL

Geology and Ourselves

By F. H. Edmunds (*Hutchinson's Scientific and Technical Publications, London, 1955, 256 pp., 10 plates. 21s.*)

To the man in the street the science of geology appears to be far removed from his everyday life; in actual fact the increasing amount of geological knowledge materially assists in making life fuller, and possibly longer, than it was a hundred years ago. The most obvious contribution made by the geologist is the location of new deposits of coal, oil and more recently of the raw materials for atomic power. A little less obvious is the increasing development of mineral resources for our metallurgical and building industries; one of the important developments that has affected everyone has been the availability and abundance of water. In all this the geologist plays an important part, firstly through the compilation of geological maps and secondly by interpreting this fundamental part of his work to the varied interests engaged in civil engineering, mining and water supply.

This book is written by a geologist with a wide and varied experience of economic geology. The author's aim has clearly been to show the importance of geology in our everyday lives. To do this he devotes a considerable part of this book to a very broad outline of the science. Whilst there is much to commend the use of introductory chapters, there is also likely to be criticism by geologists on the score that some essentials are either inadequately or too fully described. The layman, on the other hand, might find the concepts of isostasy and the geosyncline slightly discouraging; the latter concept is certainly not clarified by Fig. 2 in the text. The chapter on minerals, rocks and fossils, whilst containing a simple classification of igneous rocks and an explanation of the origin of many terms, does not contain a single illustration of either a mineral or a fossil—surely a serious omission when the book is intended for the general reader. A further criticism, which readers of the book may raise, is that the brief résumé of the stratigraphical succession does not really serve a useful purpose to either layman or geologist.

It is after these introductory chapters, however, that the topics which are likely to interest all readers are discussed. The account of the importance of geological surveys, maps and memoirs is excellent. After it comes a very full account of some problems of water supply, artesian wells and of water storage. The chapter devoted to building stones covers many aspects of the distribution of raw materials and the means of obtaining them; unfortunately there are no photomicrographs, no illustrations or descriptions of the common building stones, so that some readers may wonder what it is all about. Subsequent chapters on engineering geology, coal and metalliferous mining, and the wider aspects of the subject are all of major interest. Here the presentation will encourage further reading. The avenues for exploration by the amateur are summarised in the final chapter.

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F. A. HENSON

The Unknown—is it Nearer?

By E. J. Dingwall and John Langdon-Davies (*Cassell and Co. Ltd., London, 174 pp., 10s. 6d.*)

Recently in a television programme a young lady had a tooth removed under hypnosis and later this same lady was hypnotised by a person who was present in another room. I hope both events were duly noted by the Society of Psychical Research, for the authors of this book suggest that every person who comes under any "influence" should report his experience. Parapsychology is still in its infancy and one of the reasons for writing this book is to emphasise the fact that every reader is a potential source of information, and so may contribute to the knowledge which one day may provide the answers to many unknown factors governing this subject.

The authors make a strong plea for dealing with this subject in a totally scientific manner so that facts concerning the unknown will be gathered.

At present many of the theories which have been expounded about the unknown have been built on faulty and insufficient evidence, and very often under extremely indifferent research techniques. The authors state that the results to date satisfy only a small proportion of their hopes. Yet this criticism can be applied in some measure to many sciences, and scientists would be the first to admit that there are still many unsolved mysteries in different fields even under modern research conditions.

There is a fascinating account of laboratory research into extra-sensory perception by means of the card-guessing techniques of Dr. Rhine and Dr. Soal in which Zener packs of cards are used. The authors describe how the unknown is being brought nearer by careful study of each kind of psychical phenomenon, and they illustrate and suggest how readers can study it from his or her own experiences. Suggestions can explain a great deal: for example, Anton Mesmer cured people by mesmerism and it was only because ether and chloroform came into use about the same time that these methods replaced mesmerism. Mesmer's use of cauldrons and magnetic wands were unscientific and his theories were wrong, yet he did obtain results. Today, under the new name of hypnotism, there is a return to its use by medical scientists.

There are interesting chapters on automatisms, telepathy, clairvoyance, precognition, radiesthesia and other aspects of this fascinating subject; there are accounts of "happenings" which seem to suggest that certain phenomena do exist. The question is, how can these experiences be explained? The authors have tried to induce readers to take this subject out of the realms of fantasy. They maintain that only by a careful probing of the facts of each case and by applying modern scientific methods can we ever hope to approach the day when we shall solve the unknown.

H. HOGGAN

A Laboratory Manual of Quantitative Inorganic Analysis

By R. Belcher and A. J. Nutten (*London, Butterworths Scientific Publications, 1955, 337 pp., 25s.*)

The authors have designed this book as a practical teaching course for universities and technical colleges.

They state at the outset that they consider it essential that practical tuition should be supplemented by theory, the aim of which is to give the student a grasp of (1) the physico-chemical principles involved, and (2) the general background of the methods employed.

No extensive physico-chemical treatment of the subject is attempted, but references are given to recommend sources of information. The general background of the methods described is given quite fully in the text.

The work is divided into five main sections dealing with Apparatus and Technique, Gravimetric, Titrimetric and Colorimetric Analysis, and a final section describing some typical industrial analyses.

For the student there are included fifty-three review questions covering the subject-matter of the book.

The Appendix contains some helpful tables of information relating to acids, bases, primary standards, indicators, etc.

Author and subject indexes are provided; though the horizontal alphabetical arrangement of the former is unusual and a little confusing at first.

The Analytical sections have been treated as a series of monographs. The Gravimetric section deals with selected metals and radicals chosen to familiarise the student with the different types of precipitate and some of the newer techniques and reagents likely to be encountered.

The Titrimetric section is written from the standpoint of the reagents being used, while the Colorimetric section introduces the student to some of the relevant equipment and describes typical analyses.

The literature references are collected together at the end of each section.

The main emphasis of the book is on classical methods of analysis since it is designed for university students, but some physical methods are also included.

The treatment of the Apparatus and Technique sections seems rather unnecessarily elementary and detailed since most students entering the universities may be expected to have a good grounding in this part of the subject.

For the student, this work offers, at a very modest price, a good representative introduction to the various reagents and methods employed in Quantitative Inorganic Analysis.

D. S. H.

A Laboratory Manual of Experiment in Physics

By L. R. Ingersoll, M. J. Martin T. A. Rouse (*New York and London McGraw-Hill, 1953, 286 pp., 32s.*)

This is the sixth edition of a work that has had thirty years of success The only change in authorship is the addition of Prof. Rouse to the two originals.

The firm of McGraw-Hill always produces books well and packs them with information, and there is consequently a great demand in Britain for American technical books. This one is no exception. Anyone who has had the job of doing physics experiments from instructions ill-typed on grubby cards —dog-eared, dark, inscrutable—will appreciate books like this that consist of experiments only, with detailed instructions.

Anyone with laboratory facilities can do these experiments, though he must be warned that some of the facilities are unusual, to say the least, for they include such things as a wind-tunnel and the apparatus used by Millikan in his classical work on the charge on an electron, apparatus apparently available in America through the usual laboratory suppliers! Thermionics, nucleonics, radioactivity and the acoustics of auditoria come into a book that also has the simplest of experiments on such phenomena as surface tension and friction. There is an appendix of notes on certain pieces of apparatus and another giving tables of logarithms, reciprocals, squares and other numbers useful in physical calculations.

What appears to be missing is any warning to the new student that averaging the results of an experiment is valid only when the variation is small and random. The arithmetical average of, say, 96, 48, 32 and 104, is certainly 70, but with such a set of figures this average has no meaning whatever. The young student's delight in uncomprehending averaging is an obstacle to the understanding of scientific method.

But one cannot have everything. This book can be recommended to anyone wishing to do experiments in physics.

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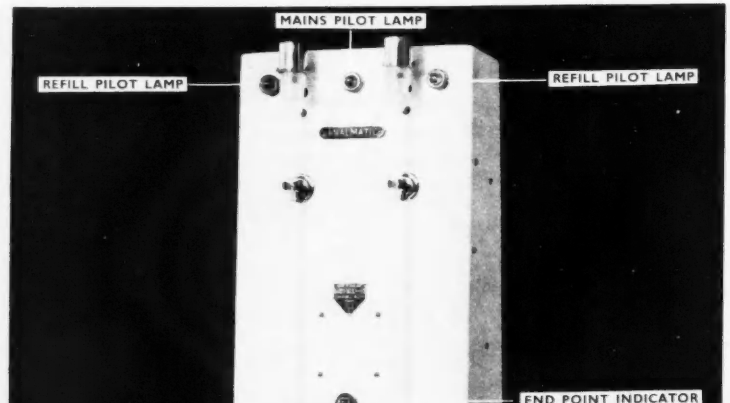

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This new clock is not only interesting on account of the ingenuity of the mechanism, nor because of the implication for the punctual running of the trains in Switzerland, but because a high philosophical, or scientific, principle is embodied in the design.

The seconds hand is meant to move continuously round the dial in 58·5 seconds, thus having some leeway in case of A.C. frequency change. At each minute it waits the necessary number of fractional seconds, and starts off again at the exact minute, 0·00 seconds. The traveller would be inclined to use the "minute" graduations for reading the seconds; but that would obviously not be quite exact—though the error would be small and only of the order $\pm$ 1 second at worst. The philosophical Swiss have obviated any such possibility of "reading" error, by giving the seconds hand not a "needle" end but a rounded disc end, so that it is not possible to read off the time more closely than to the nearest second or so. That is to say, an observational error has been deliberately built in which is of the same magnitude as the error built, for other reasons, into the running of the seconds hand. Thus any pretence that the seconds can be read more accurately than the operation of the machine allows, has been completely avoided.

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FAR AND NEAR

Night Sky in April

The constellation Virgo—a well-known spring constellation—is now in view although it never rises far above the horizon in the British Isles. Its brightest star, α Virginis, generally known as Spica, is easily found by drawing an imaginary line through α and γ Ursae Majoris, or in other words, through the first and third stars of the Plough, and producing the line about six times as far as the distance between these stars. The line will pass close to Spica which is almost south at 10.50 p.m. at the end of April and of course towards the south-east at the same time earlier in the month. This bright star of a bluish-white colour cannot be seen as a double star but the evidence of the spectroscope shows that it has a close companion a little more than 6 million miles from Spica and that both stars are revolving round their common centre of gravity in four days. It is about 230 light-years from us and readers can easily compute this distance in miles by remembering that a light-year is 6 million million miles. Knowing its distance, brightness and other details, its luminosity has been found to be about 1700 times that of the sun.

The following information about the planets will be helpful to those who are interested in observing these bodies. At the end of the month *Mercury* sets at 9.25 p.m.—just two hours after sunset—but as the moon is full on April 25 it will be difficult to see Mercury. Earlier in April it sets too soon after the sun to be favourably observed. *Venus* sets at 11, 11.35 and 11.40 p.m. on April 1, 15 and 30, respectively, and cannot be mistaken for any other planet or a star as its brightness greatly exceeds that of any of these. Seen through even a small telescope it will present the appearance of half-moon. *Mars* rises in the early morning hours—at 3, 2.35 and 2 a.m. at the beginning, middle and end of the month, respectively—and lies rather low in the constellation Sagittarius. *Jupiter* is more conveniently observed because it is visible throughout the night until the early morning hours, setting at 4.20, 3.20 and 2.25 a.m. on April 1, 15 and 30, respectively. It is in the constellation Leo and is much brighter than Regulus, the brightest star in Leo, lying west of this star. *Saturn* rises at 11.5, 10.5 and 9 p.m. at the beginning, middle and end of the month, respectively. It lies low in the constellation Scorpius near the star β Scorpii with which it is comparable in brightness (it is very much fainter than Jupiter). To assist in identification the following planets are fairly close to the moon on the dates given: April 4, Mars; April 14, Venus; April 19, Jupiter; April 27, Saturn. The Lyrid meteors, normally visible in the third week of April, will be difficult to observe owing to moonlight.

Sir Harold Spencer Jones

The services of Sir Harold Spencer Jones, K.B.E., F.R.S., who recently retired from the position of Astronomer Royal, have been retained in a consultancy capacity by the well-known Smith Group of Companies, who manufacture automobile, aviation, marine and industrial instruments and clocks and watches.

Benjamin Franklin's Asbestos Purse

In honour of the 250th anniversary on January 17 of the birth of Benjamin Franklin (1706–90), the Department of Mineralogy at the British Museum (Natural History) is exhibiting the asbestos purse sold by Franklin to Sir Hans Sloane in 1725. The purse came into the collections of the British Museum at the time of its foundation in 1753, on the death of Sir Hans Sloane. It was not identified until 1938.

When Franklin came to England at the age of nineteen to learn the printing trade, he sought to augment his income by the sale of some curiosities which he had brought with him from America. One of these, the asbestos purse, is referred to by Franklin in his autobiography, and also in a letter to Sir Hans Sloane, now in the British Museum. The purse represents perhaps the earliest specimen of asbestos from North America to reach this country.

Nuffield Foundation Awards

The Nuffield Foundation is again offering scholarships and bursaries covering a one-year period, for post-graduate training in biology and sociology.

The biology awards are intended for graduates in physics, chemistry, mathematics or engineering, and the sociology awards for graduates in the natural sciences and the humanities. Their purpose is to attract into, and train for, these subjects a few graduates who already have the advantage of having followed other disciplines.

Scientists in Ceylon

A more rational and more productive use of one-third of the earth's surface—the estimated 38 million square kilometres lying in the humid tropical regions—has been studied by an international group of scientists who met in March in Ceylon under the sponsorship of Unesco.

The meeting was opened on March 19 with a three-day symposium at the University of Colombo on the study of tropical vegetation. Studies of medicinal plants were among the subjects discussed by specialists from Belgium, Ceylon, India, Indonesia, Malaya, the Netherlands, Pakistan, the Philippines, the United Kingdom and the United States.

Following this symposium, twelve scientists participated from March 22 to March 24 in a preparatory meeting in humid tropics research to examine specific activities for the near future. Among projects proposed were the production of badly needed maps of humid tropical regions, the classification of vegetation within these regions, the organisation of a zoological survey of Ceylon, and the organisation of a Unesco-sponsored advisory committee for humid tropics research.

Perkin Centenary Celebration

During the Easter vacation of 1856 William Henry Perkin, working at his home in Shadwell, London, produced the first synthetic dye on a small experimental scale. In late 1857 the new dye, mauveine, was being sold to textile dyers and printers as "Aniline Purple". In this short period Perkin had not only devised a process for the commercial manufacture of the first synthetic dyestuff, but he had also initiated technical service by visiting users of his product, showing them how to apply it and helping them to overcome the technical problems which arose.

A full programme of events has now been arranged to celebrate the centenary of Perkin's great achievement. For further details apply to R. J. Smith, c/o I.C.I. Ltd., Woburn Lodge, Upper Park Road, Salford 7.

Art and Microchemistry

Micro-analytical techniques are indispensable in the scientific examination of paintings and other works of art, since the very nature of the objects permit the taking of only minute samples. In the case of paintings, microchemical methods have been devised for the identification of pigments and media. Modern specific organic reagents for the detection of metals have been applied to the detection of pigments using Feigl's spot test technique. This has certain advantages over the previously used microscopical precipitation reactions; for example, it can be carried out on individual layers of a paint sample mounted in a synthetic resin as a cross section. On occasion, spectrographical and spectrophotometrical methods are used to supplement microchemical methods.

The technique of partition chromatography has recently been used for the examination of paint media, both tempera (protein) and oleo-resinous. For the latter a special reversed phase system has been devised in the National Gallery Laboratory.

A scheme for the quantitative analysis of bronzes and other metallic museum objects has been worked out using micro-deposition supplemented by photometric methods using organic reagents. Finally, micro spot-tests have been applied for specific purposes in museum work, e.g. the iodine-azide reagent for the identification of niello

and a phosphate test for classifying early English porcelains. A paper on the subject was presented to the Society for Analytical Chemistry by Dr. A. E. Werner.

Wellcome Trust to Increase its Support for Research

In the past the Wellcome Trust has made a number of notable benefactions, including the endowment of a Wellcome Chair of Tropical Medicine and a Wellcome Chair of Pharmacology in the University of London. The Trust recently made a grant of £100,000 which met the cost of the three large museum floors in the new building of the Royal College of Surgeons.

Chairman of the Wellcome Trustees is Sir Henry Dale, and he has explained that the Trustees' past policy has had a certain opportunist character. "They have in general tended to reply to appeals made to them for benefactions, some of them of large dimensions, rather than to initiate a planned policy of their own for spending the substantial resources, which under normal conditions, they should now be able to regard as regularly at their disposal. The time having now come for such a longer-term policy and a more co-ordinated planning by the Trustees, they have recognised the need for a whole-time administrative staff to deal with the charitable aspect of their functions."

Between 1936 and 1953 the Trust disbursed about £500,000, but its financial position now enables it to increase the scale on which it supports medical research by benefactions. Dr. F. H. K. Green, who has been Principal Medical Officer on the Headquarters Staff of the Medical Research Council, has just joined the Trust as its Scientific Secretary to undertake the chief responsibility for the executive organisation of the Trust's spending policy.

Expansion of University College, London

Since 1945 London University College has had an uphill task in carrying on its work. It suffered very heavy war damage. Well over £1,500,000 has since been spent on post-war reconstruction of the College, but part only is recoverable from war damage claims. The balance has been met by sums from the University Grants Committee and other sources. The initial response to an appeal for funds for new engineering buildings has been most encouraging. It is pointed out that graduate engineers are qualifying at a rate that falls far short of the national demand. Owing to inadequate accommodation and facilities, the College can accept only one of every nine applicants, and of these nine, at least seven are fully qualified and suitable for entry to the Engineering Department.

The College's present yearly output is approximately seventy graduate engineers, but as soon as the first stage of the building programme can be completed, this output will be stepped up by 50%. If their £2 million appeal is met in full, the College will be able to accommodate about 600 engineering students, corresponding to an annual intake of about 200, including candidates for higher degrees.

New Laboratories

PROF. J. HEYROVSKY, who invented the polarograph in 1925, recently opened the new polarographic laboratory set up by the Cambridge Instrument Co. Ltd. adjacent to its Cambridge works. The head of this laboratory is Mr. W. J. Barker.

A new research department has been set up by Hoover Ltd., at Perivale, Middlesex; it will have as its function the harnessing of electronic and other scientific discoveries and techniques for use in new Hoover products. Its director is Dr. David Martineau Tombs, a New Zealander, who was until recently Senior Lecturer in Telecommunications at the Imperial College of Science and Technology.

Continued on p. 176

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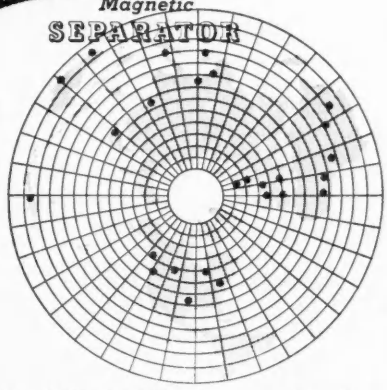

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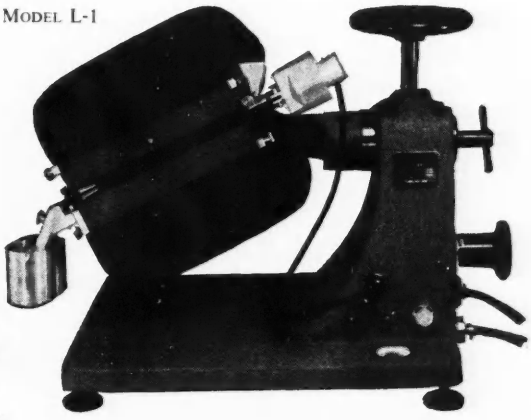

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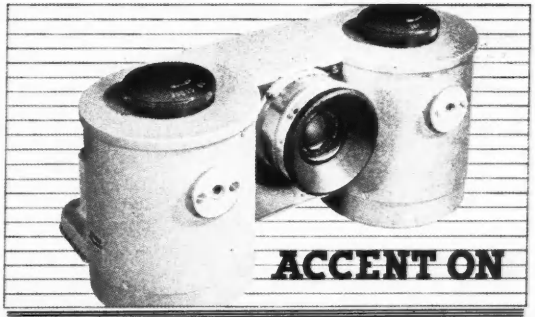

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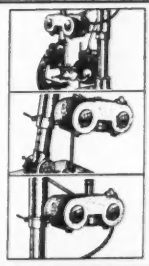

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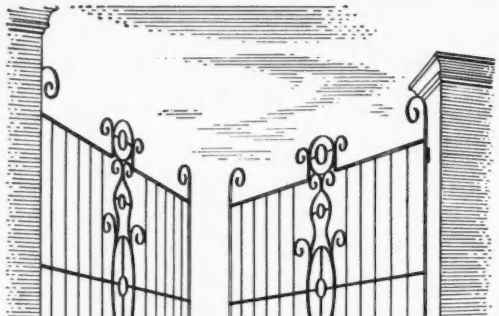

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FAR AND NEAR—continued

CERN's Budget

The 1956 budget for CERN (European Organisation for Nuclear Research) has been fixed at about 34 million Swiss francs as compared with last year's figure of 25 millions. 1956 will be a period of great constructional activity, a general move to the site at Meyrin, and the installation of the laboratories and workshops. By the end of 1960 CERN, it is estimated, will probably have spent about 197 million francs. The cost of providing adequate foundations to carry the huge weight of the proton synchrotron has proved higher than was anticipated. By 1960 the staff will then probably be stabilised at around 500 members.

CERN is arranging to hold a symposium on High Energy Physics in Geneva in the fortnight June 11–23, probably in the Institute of Physics of the University of Geneva.

Polio Vaccination in Britain

British production of the modified Salk vaccine (which involves a less virulent strain of polio virus) has reached the stage when large-scale vaccination can begin. In January the Minister of Health said it was hoped to inoculate between a quarter and half a million British children aged 2–9 in the early summer. Parents of children born between 1947 and 1954 who wish to have their children vaccinated should apply to their local health authority when invited to do so at the appropriate time. The scheme will be completely voluntary; no child will be vaccinated without the written consent of a parent or guardian. After November it is expected that the supply position will make it possible to extend the vaccination to other age groups. A Gallup poll (published in the *News Chronicle* of January 24) has shown that a high proportion of parents are eager to take advantage of this vaccination scheme.

Cosmic Ray "Telescopes" in the Antarctic

Two cosmic ray telescopes, claimed to be the largest in the world, are now in operation at Australia's Antarctic station at Mawson. They will enable scientists to make a continuous study of fluctuations in cosmic ray intensity. The physicist in charge of the scientific work at Mawson, Mr. Neville Parsons, has had the "telescopes" erected on converted anti-aircraft gun mountings set in concrete piles weighing four tons. The apparatus contains 230 radio valves and 150 Geiger counters. The development of the "telescopes" represented two years' work by Dr. Geoffrey Fenton and his associates in the Physics Department of the University of Tasmania.

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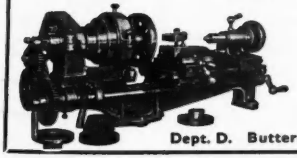

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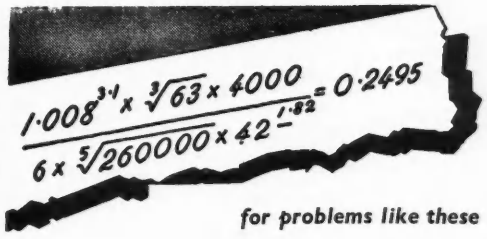

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(BLOCK LETTERS, PLEASE)

Address.....

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" There's nothing like a *black* car ", say the Old School. "A metallic grey job never shows the dirt ! ", retorts the modern salesman. " Fire-engine red ", sighs the sports-car enthusiast (absent-mindedly changing down with the bowl of his pipe). What *are* the popular colours ?

Colourful types

To find out, I.C.I.'s Paints Division — leading suppliers of paint finishes to the British motor industry — carry out every year a survey of all British cars at the Earls Court Motor Show. So far, despite the coming of pastel and metallic shades, black still remains favourite.

Assessing trends in public taste is only one facet of Paints Division's service to the motor industry — service that dates from the early days of mass-production. It was I.C.I.'s introduction of the quick-drying cellulose finishes, for example, that reduced the time taken to paint cars from 12 days to 12 hours. Today, Paints Division continues the search for better finishes, primers, and undercoats, and its products are protecting and decorating not only motor vehicles all over the world, but also ships, aircraft and many other products — as well as the factories and homes where people work and live.

Thus, and in a thousand kindred ways, I.C.I.'s research and production are serving the Nation.

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